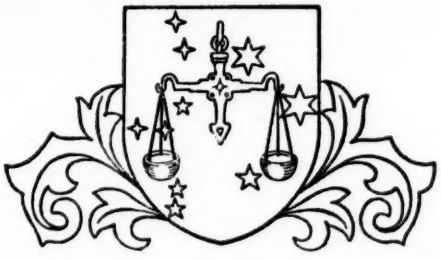
1831  1950

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BIRMINGHAM MEETING, 1950

JUDGED by the standards of previous years and by the comments of many who were present, the 112th Annual Meeting of the Association which was held at Birmingham from August 30 to September 6, was an outstanding success. It is true that the science correspondent of *The Daily Express* (which published unbalanced and relatively insignificant reports of the sessions) and the editor of *Discovery* (whose October number carried a highly commendable 14,000 word factual report) both thought it necessary to question the success of the meeting. The former described it as 'lifeless,' but yet another newspaper correspondent (drawing upon a longer experience of those meetings) referred to the week as having ' recaptured some of the great vital spirit of science ' and ' set an example hard to maintain.'

It would appear from this and from many other portents that the Association's meetings will continue, as always, to rise to the occasion or fall short of perfection according to the needs and expectations of the many people who attend them—and there were over 3,700 members at Birmingham. One of them, attending for the first time wrote ' in the words of the play which I was unable to attend (Much Ado about Nothing, at Stratford on Avon) my first meeting *hath indeed better bettered expectation than you must expect of me to tell you how.*'

The meeting was the sixth to be held in Birmingham and the second there in this century, the previous visit having been held in 1914. The Sections met then in the centre of the city, but on this occasion the Association was fortunate to have such generous access to the well-equipped University Buildings at Edgbaston, with which the Training College for Teachers, the fine buildings of the Medical School and the magnificent modern buildings of the King Edward VI Schools, provided an admirable centre for the simultaneous sessions of the thirteen Sections and made relatively easy those movements from one Section to another which are a feature of the Association's meetings.

On such a pleasant open hill site, dominated by Chamberlain's unique clock tower it would have been easy to imagine oneself deep in the country, but the occasional sound of a drop forger's hammer served as a reminder that the University and adjacent institutions were set in the midst of a great industrial community, who, through the agency of the City Council, were also hosts of the Association. The fine Town Hall, the Council House and Art Galleries, the Midland Institute and the Digbeth Institutes were all parts of the pattern of the meeting.

The Reception Room was opened on the morning of Tuesday, August 29, in the University Union which was put at the disposal of the Association by the Guild of Undergraduates who also generously elected all members of the Association to temporary membership of the Union. The Association has rarely had access to a building better suited for its administrative and social centre and here for the following week was a scene of ordered and orderly bustle. By the time the Reception Room opened it was already obvious from registrations both in London and in Birmingham that the meeting would be a large one. Further registrations in the Union ultimately brought the total to 3,744 which has been exceeded only twice before at meetings of the Association in the British Isles—at the Centenary Meeting in London in 1931 and at the Manchester Meeting in 1887, the year of Queen Victoria's Jubilee.

About half of those present were resident in the Birmingham area and included some 300 teachers of science in local schools. Among the visiting members there were many from overseas, notably the President of the French Association, the President and Secretary of the Indian Association, the Secretaries of the Pakistan Association and of the South African Association, a Vice-President of the Brazilian Association and a representative of the American Association. There were also present by special invitation other distinguished men of science from nine countries. Notable absentees, who were greatly missed, were Dr. J. B. Conant, President of Harvard University, who was prevented by an operation from coming to give an address on the study of science by non-scientists and Professor Karl von Frisch, of the Zoological Institute at

Munich, whose health prevented him from making a journey by air, as he had planned, to lecture on The Language of Bees. The visiting members also included delegates from about 40 scientific societies and the representatives of 18 Corporate Members.

Wednesday, August 30.

In the afternoon there were meetings of the Council, General Committee and a few of the Sectional Committees. The General Committee received and approved the Council's report for the year in which one of the more important items was an announcement that Down House, held by the Association since 1928 as a national memorial to Charles Darwin, was likely to become a residential tutorial centre under the triple responsibility of the Association, the University of Oxford and the Kent County Council.

The General Committee was addressed by Officers of Associations for the Advancement of Science overseas, and their presence at the Annual Meeting, welcome at any time, was doubly welcome because it provided opportunity to discuss proposals for closer co-operation between all Associations, proposals which were due to be considered at a meeting in Paris on September 8 and 9 under the auspices of Unesco.

In the presence of the General Committee Sir Raymond Priestley, on behalf of the Local Executive presented to the Association a gift of 30 badges to be worn by Presidents and Recorders of Sections. The badges were designed by Mr. R. G. Baxendale and made by the Birmingham Medal and Badge Company in silver and lacquer (blue for Presidents, green for Recorders). In returning thanks for this magnificent gift the President said that badges would greatly assist members to identify the Officers of Sections and would serve for many years to come as a reminder of the generosity of Birmingham to the Association.

Members not directly concerned with those meetings spent their first few hours in a variety of ways. Most of them, as it seemed, reported at the Reception Room or at the Section Rooms to collect excursion tickets. In all there were 52 general and 68 sectional excursions and visits to choose from, with places for 7,000 people. With such a wide variety of industry at hand and with ready access to some of the finest country in the heart of England, and with so many generous hosts ready to open their doors to members of the Association, it was not surprising that an exceptionally rich choice was available. Through the generosity of the Local Committee and the City Council, copies of two local publications had been posted in advance to all who had notified their intention to be present at the meeting. These were the *City of Birmingham Handbook* and the Scientific Survey *Birmingham and its Regional Setting*. The members were thus able, if they wished, to make a study of the region before their arrival.

Members also had the opportunity on the opening day and throughout the week to visit the very fine exhibition on Energy in the Service of Man, which, with generous local help, had been arranged jointly by the three national bodies—the British Electricity Authority, the Coal Board, and the Gas Council. This was on view in the University at Edgbaston. The exhibition was also open to the public before and after the week of the meeting and in connection with it there were five public lectures on various aspects of the theme Energy in the Service of Man. It is hoped to publish the texts in a later number of this journal.

The first general assembly on the opening day was the Inaugural Meeting in the Town Hall at which the President, Sir Harold Hartley, delivered his Address on ' Man's Use of Energy.' In spite of wet weather every seat in the auditorium was taken. Floodlit without and brilliantly lit within the beautiful Town Hall made a fine setting for the dignified splendour of academic dress and civic ceremonial. The Lord Mayor of Birmingham, Alderman A. Paddon Smith, welcomed the Association to the City, the President delivered his Address and Sir John Russell, immediate past-president proposed a vote of thanks. The President's Address has been published in full in *The Advancement of Science* (September 1950) and in *Nature* (September 2, 1950). It was broadcast direct in the Third Programme and a recording of a shortened version was transmitted in the Home Programme. At the end of the meeting the President made some announcements which included the result of the Endeavour Prize Essay Competition to which reference is made at the end of these notes.

Thursday, August 31.

The Committees of all Sections met soon after 9.0 A.M. to confirm their programme and transact other items of business. The public sessions began at 10.0 A.M. and four of the Sections (Chemistry, Zoology, Engineering, and Agriculture) opened with the Addresses of their Presidents. Two others (Psychology and Botany) had their Presidential Addresses at noon after the reading of other papers. The full texts of all Presidential Addresses have already been published (*The Advancement of Science*, October 1950) and summaries appeared in *Nature* (September 2, 1950). The Physics Section began with a session on high energy particles and machines for their acceleration. This was opened by Professor R. E. Peierls and the last paper, by Professor P. M. S. Blackett, was one which came very near to being what

some people think there should be more of at meetings of the Association—namely a first announcement of a new discovery. In his communication on very heavy unstable mesons, Professor Blackett announced confirmation of the existence of new particles called V particles on account of the shape of their disintegration tracks. The evidence was obtained by British research workers in an observatory at 9,000 feet on the Pic du Midi (whose first photographs of the disintegrations he produced) and by Americans at Pasadena.

In the afternoon of Thursday all but four Sections had excursions. The Conference of Delegates of Corresponding Societies was opened with the Presidential Address, which is published in this issue.

In the evening the members of the Association were guests of the City at a Civic Reception in the Council House and Art Gallery. Over 2,000 people were received by the Lord Mayor and the Lady Mayoress (Mrs. Donald Paddon Smith) and entertained with music, dancing, two concerts and refreshments. It was a memorable occasion.

Friday, September 1.

The Presidents of the Sections of Geography, Economics, and Education read their Addresses and the programme for this day included five discussions in which two or more Sections were involved. The joint sessions were concerned with presentation of technical information, the functions of the skin of vertebrates, the climatic limits of vegetation, the chemistry of the cell, and the theory of continental drift. The discussion on Wegener's Theory that the continents have drifted apart was of interest to geographers, geologists, geophysicists and biologists and drew a crowd which packed the biology lecture room. In six prepared papers and the spontaneous discussion which followed there were ranged on opposing sides the biologists and the physical scientists. At the end the Chairman, Dr. W. B. Turrill, invited those present to vote for or against continental drift and the result, roughly assessed by a show of hands, was a dead heat. In the Physics Section there was such a demand for places at a session on civil applications of atomic energy that the Section migrated to the University's Great Hall. Speaking on the prospects of obtaining power on a commercial scale from nuclear piles Sir John Cockcroft gave no hope that this would be available within the next five years or that its cost would be any less than the cost of power obtained from coal. In the Education Section Dr. Eric James, High Master of the Manchester Grammar School, deputised at short notice for Dr. Conant and gave a most stimulating and challenging address on Science in the general education of the non-scientist. During the week the Education Section succeeded in getting on its platform the Headmasters of Eton, Winchester, Manchester and Birmingham, which was surely a most unusual event at a scientific conference.

In the evening there were several section dinners and an audience of some 600 people, disappointed to miss Professor von Frisch, were richly rewarded by coming to hear Dr. W. H. Thorpe deliver a discourse on The Language of Bees, which was based on von Frisch's notes and illustrated by a film flown from Munich for the purpose.

Saturday, September 2.

There were no sectional meetings but it was nevertheless a day full of activity and interest. By 10 A.M. some 1,200 members had left the City on over twenty excursions, many of which lasted the whole day. The President joined chemists on the first stage of their visit to Nechells Gas Works, where he opened a new £100,000 research centre, the largest outside London. The President then returned to Birmingham where, at a special Graduation Ceremony at noon in the Great Hall of the University, he was presented by the Public Orator for the honorary degree of Doctor of Science which was conferred on him by the Vice-Chancellor. Sir Harold Hartley delivered an Address. The ceremony was followed by lunch at King Edward's School.

In the afternoon in brilliant sunshine about 1,000 members were entertained at a garden party at Bournville by invitation of Cadbury Bros., Ltd., who, like many other firms in the district also received parties of members during working hours.

The day ended with a reception and dance at which the University were hosts, the main building, now familiar to the members, having been quickly transformed by a quiet genius. The Pro-Chancellor received.

Sunday, September 3.

The President, the Lord Mayor, the Pro-Chancellor and the Vice-Chancellor, with several hundred members of the Association attended a non-denominational service in St. Martin's Church. The Dean of St. Paul's, Dr. R. W. Matthews, preached the sermon. In it he said that the assumption that mankind grew kinder, more tolerant and more just as civilisation became more efficient was but an illusion. He believed that the power of God to make new men could banish the fear of those who stood at the cross-roads knowing that they could not meet the demands made upon them.

Before an audience of over 1,000 people in the Great Hall, the Bishop of Birmingham, Dr. E. W. Barnes, delivered an evening discourse on Science, Religion and Moral

Judgments. Putting the question: ' Is human life always sacred, whatever its quality or circumstances ? ' he dealt in turn with ethics of euthanasia, suicide, sterilisation, abortion and atomic warfare. The discourse received much attention in the press and was published in full in *Nature* (September 16, 1950).

Monday, September 4.

The Presidents of four Sections (Physics and Mathematics, Geology, Anthropology, and Physiology) and the Chairman of the Forestry sub-Section delivered their Addresses and, in addition to individual papers, there were nine major discussions of which two were intersectional. The joint discussions dealt with genetics in relation to classification of plants and animals and with social factors in productivity. The other topics included chromatography, production engineering, digestive hormones, protection of plants against pests and heat flow in the earth's crust. One of the outstanding individual contributions was a paper by Sir Ewart Smith on the importance of higher technological education in relation to industrial productivity, which is published in this issue.

One of the afternoon meetings was the second session of the Conference of Delegates which was addressed by Sir Patrick Duff on National Parks.

In the evening five Sections held dinners and the engineer members were entertained at a Conversazione. In spite of these counter-attractions there were large audiences at both of the general meetings arranged for this night. In the Great Hall Dr. A. C. B. Lovell delivered an illustrated discourse on The New Science of Radio Astronomy, and in King Edward's School there was a discussion on The Dearth of Science Teachers, which was arranged by the Division of Social and International Relations of Science.

Tuesday, September 5.

This was another very full day. Eight main discussions started simultaneously at 10.0 A.M. and one of the joint sessions lasted all day. This was a discussion on The Rehabilitation of Derelict Areas, which was opened by Sir John Russell. In the Chemistry Section there was a discussion on Chemical Energy, which will be remembered not only for the high standard of the papers but also by the novelty of some of the demonstrations given by Dr. James Taylor. The Mathematics sub-Section drew large audiences for two very different papers, one on The Meanings of Time and Space in Philosophies of Science, and the other on Problems connected with Football Pools. The Great Hall was once again well filled in the afternoon for a popular illustrated lecture on The Badger, by Mr. Ernest Neal.

In the evening biologist members were entertained at a Conversazione as guests of the Birmingham Natural History Society. The President, Council and principal officers of Sections held a dinner in honour of overseas guests and of local officers who had contributed so much to the success of the meeting.

Wednesday, September 6.

For the last morning only five sessions were arranged, one of which, on dating the past by means of carbon 14, was the concern of two Sections. A three-hour programme of scientific films was presented by the British Universities Film Council and this, for many members, was the last engagement of a memorable week.

At a meeting of the General Committee held at noon the following resolution was passed with sincere acclamation:

' At the close of this mid-century Meeting in Birmingham the General Committee resolve to place on record their appreciation of all that has been done in the City, the University and the surrounding district to make the Meeting one of the most memorable in the long history of the Association, with the remarkable attendance of 3,744 members.

The General Committee express sincere thanks :

(i) To every kind, generous and thoughtful host ;

(ii) To the Lord Mayor of Birmingham, the City Council, the staff of the Council House, and the friendly people of this great City ;

(iii) To the Pro-Chancellor and the Vice-Chancellor, the staff of the University of Birmingham and the Guild of Undergraduates ;

(iv) To all firms and other hosts who opened their factories or homes to receive parties of members of the Association.

(v) To the National Coal Board, the British Electricity Authority and the British Gas Council and their staffs, for staging a most interesting and instructive Exhibition on Energy in the Service of Man.

(vi) To the Boy Scouts who, by their willing and unobtrusive service in countless ways made the wheels of the organisation run so smoothly.'

Essay Prizes.

In connection with the meeting the publishers of the quarterly review *Endeavour* sponsored a competition in which scientists not older than 25 submitted 4,000-word essays on one of twelve subjects. There were 117 competitors and the prizes were awarded to W. J. T. Dunstan (London), S. J. Adelstein (Harvard), F. J. C. Rossotti (Merton, Oxford), and a special prize to R. D. Cohen (Bristol), for an essay of special merit for an author only 17 years old.

A prize offered by the Council for the best essay on the Birmingham Meeting by a student Exhibitioner was shared by J. M. Carr (Durham) and M. J. Lavoipierre (Liverpool).

THE FOURTH
RADFORD MATHER LECTURE

SCIENCE AND THE ADVENTURE OF LIVING[1]

by

SIR LAWRENCE BRAGG, O.B.E., F.R.S.

A LECTURER invited to give an address of this kind must ask himself the question 'What was in the mind of the founder? How can I interpret his wishes?' This is especially the case of the Radford Mather lecture, which I understand to be intended to deal, not with some special field in science, but with the much broader question of the relation of science to the community as a whole. This is indeed a formidable challenge to a lecturer. He must leave the ivory tower of science where he is concerned with Nature alone, and enter a field where economic, aesthetic, moral and religious values play their part. I confess I approached this task with some trepidation, because when one tries to talk about one's convictions any illogicality, ignorance or triteness is so mercilessly exposed. It would be far easier to take the safe path of describing some recent achievements of science and showing how they give us greater command over Nature, better means of communication, more plentiful food, and better prevention of disease. Such a line would perhaps have seemed the obvious one to take in the optimistic spirit of the beginning of this century. But I feel strongly that to take it nowadays is to avoid the real issue when talking about Science and the Community. The optimistic spirit has been replaced by one of doubt and questioning. Thinking men and women are wondering whether after all the benefits science has conferred outweigh the complications of life which have also resulted from its applications, and in particular the greater power of devastation which it has made possible in clashes between nations. It is my belief that these doubts arise from taking too narrow and shortsighted a view. But there is no doubt that the scientist must meet a challenge which would not have concerned him a generation ago.

Rather therefore than talk about recent technological advances made possible by science I shall try to put in perspective the broader significance of 'The Advance of Science.' How does it rate as event in the history of mankind? I accept the view so frequently expressed by students of social problems that it is one of the major events which at long intervals quite transform the whole nature of human life. To be more specific, the discovery of the scientific method, and the vastly increased power to penetrate the secrets of Nature and the control over its forces which have risen directly or indirectly from the advance of science, comprise an event comparable in importance to the change from a hunting or pastoral to an agricultural way of life. The fact that we are increasingly being able to do things we could not do before is so obvious and so accepted as a feature of everyday life nowadays, that its very familiarity makes it hard for us to stand back and assess its importance in a quantitative way. Any graph of what is materially possible—speed of travel, speed of communication, mechanical power available to the individual, mining of metals from the earth, availability of new materials—would run almost level for the last few thousand years, or with only a slight upward tendency, and then rise in the last century or so as an exponential curve. There is as yet no sign of the curves falling away again, we are apparently on the initial part of the rise. Surely anyone viewing with an open mind the trend of these curves must be driven to the conclusion that one of the great events in human history is taking place. It signifies that mankind is entering upon a new phase of existence, such as last happened when the development

[1] Delivered at the Royal Institution, London, on October 25, 1950.

of agriculture made it possible for the first time to live in settled communities and not be wanderers on the face of the earth. Agriculture made possible the existence of cities, and thus was the material foundation on which 'civilisation' as distinct from barbarism was built, with all its new crafts, arts, aspirations, complexities and dangers, its power to rise to greater heights or sink to more profound degradations. What we are witnessing at present is the start of a new era, a mysterious unknown 'x' which will bear in importance the same relation to civilisation that civilisation bears to barbarism. If I seem to be repeating what has so often been said before in much better words than mine, I ask for your indulgence and understanding that I am trying to assess not the qualitative but the quantitative aspect of the problem before us. It is so easy not to see the wood for the trees, to be distracted by this or that of the many achievements which form part of the general advance and which seem so important when one concentrates on them alone. When I have talked with humanist friends in this vein they have sometimes said 'Do you really mean to imply that scientific advance is more important than the discovery of the new world or the invention of printing?' I believe these to be merely individual trees in the wood, that we are witnessing something almost infinitely transcending in importance such minor individual events. It would be misleading to imply that the whole of the change is due to the advance of pure science. It began in an age when the rise of science was one result of a greatly increased activity of invention and discovery, and at first science played a relatively minor role. But increasingly the scientific knowledge of Nature has given a keener edge to invention and discovery; it has enormously increased the rate of progress, until nowadays it is the major factor in determining this rate. In its pure form science is one of the arts; its devotees get their reward in the intellectual and aesthetic satisfaction they derive from its study. It holds a unique position amongst the arts in that it has this extraordinary power of changing the external conditions under which we live, it is an art which has transformed the crafts.

The driving power behind the advance of science is a faith. I should like to attempt an expression of this faith, because science has a great power of exciting its disciples to 'scorn delights and live laborious days.' No one who has seen successive generations of young researchers begin their careers can fail to have been struck by the hold it gets on them. In a world of shifting values and challenged authorities pure science in its own restricted field has a clear aim which transcends personalities and national boundaries. What gives it this vision? I think it to be a profound conviction that in its search for truth science has a court of appeal, a touchstone, which is independent of fallible human judgment. When one has sought long for the clue to a secret of Nature and is rewarded by grasping some part of the answer, it comes as a blinding flash of revelation; it comes as something new, more simple and at the same time more subtle, and more aesthetically satisfying than anything one could have created in one's own mind. This conviction of something revealed, not something imagined, is all the stronger because of the discipline science imposes on those who would succeed. It is so essential to come to a problem with a completely open mind, and to resist the fatal temptation to warp and select the facts so as to fit in with some preconceived idea of a tidy little universe.

There is this curious quality about the really great discoveries of science, that they carry general conviction, they only need to be expressed to be accepted. I realise of course that scientific controversies are not unknown, that there are initial stages in which violently different views are held and maintained with great heat. We must recognise too that scientific views are subject to continuous modification and restatement as knowledge advances. But I think anyone who has studied science will understand what I mean. The discoveries of the giants of the past are built upon, not discarded. They form a solid foundation to a super-structure which is added by their successors.

Thus the spur to the devotee of science is his belief that he has as his judge not 'broad rumour,' to quote Lycidas again, but 'the pure eyes and perfect witness

of all-judging Jove.' It is as if, in the restricted field of natural philosophy, we are allowed to attain a measure of absolute certainty, a glimpse of Truth herself. This belief in a scale of values transcending human judgment has an interesting consequence when questions of assessing personal achievement arise. The younger generation of artists or writers are apt to maintain with great heat and conviction that most of their seniors who are high in popular esteem are just the people who have the least claim to greatness, that only the judgment of succeeding generations can place them rightly, that genius is seldom recognised during the artist's lifetime. Such violent disagreement about relative merit is, on the whole, conspicuously absent in the scientific world, where merit receives quick recognition. The young scientific genius is not likely to starve in a garret.

The advance of science and the success with which its knowledge has been used to increase our control of Nature has raised two great questions, two problems which we must face. They are closely interrelated, in fact they are perhaps two different aspects of the same problem, but in an attempt to clarify the issues I shall deal with them separately.

The first is very finely expressed in the chapter on 'Wholeness of Living' in the report of the Commission appointed by the British Council of Churches to consider the problems raised by the era of atomic power. I wish it were possible to quote the relevant paragraphs in full, and indeed I consider the point so important that I have fallen to the temptation of making a long extract from the report. It describes two relations towards the world around one, which it distinguishes as 'Discovery' and 'Encounter.' The following quotation explains the sense in which these words are used :—

'The outlook of western society throughout the modern period has been governed in the main by a conception of man related as an individual to an external environment which it is his primary duty to explore, understand, and control for his own purposes. Modern science is the child and instrument of this attitude, and has at the same time by its successes confirmed and strengthened it. To many people to-day no other attitude is even thinkable. . . . The conviction has been growing and deepening in many minds that the course which western society has followed in recent centuries is not so much wrong in itself but disastrously one-sided, and that unless modern human life can regain its proper balance, society must collapse.'

'The reality of human existence is not what it is commonly supposed to be. Life is not, primarily, as is generally taken for granted, a vast collective enterprise in which individuals co-operate to subdue Nature for their purposes. For the setting of that enterprise is an arena in which a multitude of separately existing persons, and groups of persons, with conflicting purposes, are in continual collision with one another. That is the bed-rock fact of social existence. The texture of daily living for all those who do not take refuge in ivory towers is the adjustment of relations with other persons. . . . Though this world of encounter and contradiction, of the clash of opposing purposes, is the actual world in which we have to live, we often fail to realise that this is the real stuff of which life is made, because our minds are dominated by our habit of viewing life in terms of man's mastery over his physical environment. It is this wrong perspective that leads to the view that more science will suffice to solve our problems, and that the management of human affairs is primarily a matter of social engineering.'

The scientist lives in the world of discovery, in which there is always a beyond. He is continuously pushing back the present boundaries of understanding and achievement. He is not, as is often fallaciously thought, more withdrawn from human contacts than his humanistic colleagues. Scientific research is largely team-work carried out in laboratories where he is not only in constant communion with his fellow researchers, but also directing assistants and mechanics and making them understand what he requires of them. He is in closer everyday contact with his fellows than the man in the study or library. But it is team-work in which the same aim animates all, there is no clash of purpose. This withdrawal from personal collisions is the ivory tower in which he is tempted to seclude himself; it is not, as so often supposed, the indifference to the uses to which his discoveries may be put. That accusation, so often levelled against him, is the result of ignorance, of misreading the lesson of history. The most important factor in the rapid advance of science has been the

realisation that if pure science devotes itself exclusively to knowledge for its own sake, advance is far more rapid and in the long run useful applications far more extensive than if material ends are given a thought.

The scientists' world is therefore necessarily a much simplified one. Now the world at large can afford to have a relatively small body of men living the almost monastic life of withdrawal, but it becomes dangerous when the obvious successes of technology lead the whole community into a false perspective and sense of values. The humanists realise this danger. They are uneasy about the unbalanced emphasis on material achievement in the present age, and they are of course right. The danger at the present time is that the scientists and humanists are divided into opposite camps, neither fully understanding the other. The scientist lives in too simple a world ; the humanist, though he be uneasily conscious of the might of the genie which has escaped from the bottle, is unable to help in planning its control because he knows too little of the scientific method and its potentialities. I find it hard to define the barrier of whose existence I am often so acutely conscious when talking with a humanistic colleague. It is not due to any lack of acknowledgment on his part of the material advances of technology. It is due to something deeper, to his lack of a background of scientific knowledge and sense of values so that there is no common language in which we can talk about science, in the way we can talk together about literature or art because some knowledge and appreciation of these is a part of our common heritage. Science itself, as distinct from technology, has its great adventures in thought. Such philosophical concepts as Newton's mechanics, the quantum theory, or relativity, and such reachings out as the exploration of the universe, are thrilling. But their thrill cannot be appreciated by anyone who has not asked himself the questions to which they are such mentally satisfying answers. So the attitude of the humanist towards science is too often that of the philistine towards art, a curious blend of amusement with irritation that anyone should apparently find so admirable a work in which he ' cannot see anything to be excited about.'

The fault may well be ours. Well tested methods of making an appreciation of the arts a part of our general cultural background have long existed. We should ask ourselves whether we have given thought to expressing science in a form such that it can also be part of a general cultural background, or have on the other hand merely learned how to teach science to scientists. Whatever the origin of the barrier, I feel that it is on this level that it must be broken down, for it is of vital importance that the two sides should come together. The clock cannot be put back. The technological age is transforming our existence, not because it is giving us cars, better lighting and television sets, but because it has turned the world into a far more closely knit whole. The new world is like a higher type of organism with a more complex system of innervation and specialisation of function. What happens in one part more intimately concerns the whole. Personal values must be rephrased, and this can only be done by an integration of the humanistic and scientific outlook, for the humanists and scientists between them provide the thinkers to whom we look for guidance.

The same problem of controlling technology, but another aspect of it, received its best known expression in Erehwon. Are machines running away with us? You will remember that Butler's hero wandered into an unknown country and had a mixed reception by the inhabitants. Though commended for his magnificent physique, he was regarded with grave suspicion by the Erehwonians because a watch was found upon him. He later came to understand that the Erehwonians had been profoundly impressed by the *Book of the Machines* written by one of their sages. The author had conclusively proved that a new order of living organism was evolving, the machine, which bore the same relation to the humans who tended it that our bodies bear to the innumerable individual living cells which comprise them. Finally the machine would become the real living entity, and man would cease to have any individual existence. The Erehwonians, deeply impressed with the danger, had destroyed

all machines and gadgets of any kind and made it a penal offence to try to reintroduce them.

Aldous Huxley, in *The Perennial Philosophy*, carries the attack further and deeper. To him man's pride in his conquest over Nature may easily become the Greek 'hubris,' the pride which the gods will not tolerate and which is punished by avenging Nemesis. He quotes Alfred de Vigny, writing a generation before Butler about the first railways :—

'Tous se sont dit "Allons," mais aucun n'est le maître
D'un dragon mugissant q'un savant a fait naître
Nous nous sont joués à plus fort que nous tous.'

'They were convinced that Puffing Billy was hauling them at full speed towards universal peace and the brotherhood of man, while the newspapers they were so proud of being able to read, as the train rumbled towards its Utopian destination not more than fifty years away were the guarantee that liberty and reason would soon be everywhere triumphant. . . . For some inexplicable reason the travellers (now far from gay) still hold fast to the religion of Inevitable Progress—which is in the last analysis the hope and faith (in the teeth of all human experience) that one can get something for nothing. How much saner and more realistic is the Greek view that every victory has to be paid for and that for some victories the price exacted is so high that it outweighs any advantages that may be obtained. Modern man no longer regards Nature as being in any sense divine and feels perfectly free to behave towards her as an overweening conqueror and tyrant.'

Anyone who has spent his life in our industrial north amongst the present results of the vast riches which, due to technological triumphs, flowed for generations into what must once have been a lovely countryside cannot help feeling the sting of these words.

We cannot dismiss these attacks lightly. In discussing recent advances in science and their relation to the community, it is no answer to them to point out that recent advances in metallurgy have led to lighter and more powerful aero engines, or to talk of advances in nuclear physics, when the atomic bomb and the bomber which carries it are in everyone's minds. That is why I have felt impelled, in planning this lecture, to talk about fundamental issues. In what relation does the scientist stand to the community as a whole ? Have the technological advances made possible by science brought us nearer the millenium, or are they the contents of a Pandora's box which has released countless new troubles and anxieties upon mankind ? I believe these doubts and questionings to arise from a misunderstanding of what is happening to us at the present time, from a view just as short-sighted as the earlier optimism to which these attacks are the reaction.

In the first place, it is interesting to note the confusion they show between science and technology, and the way in which the word science is often used when technology is what is meant. The confusion is all the greater because science and technology are nowadays so interwoven, science and trained scientists are so useful to technology, and technological needs have so often inspired first-rate scientific work. Science is the search for a deeper understanding of the relations between natural phenomena, technology is the use of any knowledge we have about natural phenomena for attaining practical ends. Technology is as old as mankind itself. Science is a comparatively recent growth. Let us take, for instance, the very crudest form in which the confusion between science and technology is displayed. It is the view, which we so often hear, that scientists should only find out new knowledge which can be applied to useful or harmless ends, and refrain from any discovery which might lead to more destructive methods of war or put greater power in the hands of evil-minded men. In another form, scientists are accused of being selfish in seeking natural knowledge for its own sake, merely for their individual interest and pleasure, when they should be applying themselves to discoveries which could be of immediate general use to the community. Pure science is an exploration, a survey of new knowledge ; any particular discovery may never be useful, it may be useful for many different and totally unexpected purposes, and at any rate it will probably be decades before it affects the general life of the community, so it is impossible to have an eye on its use when discovering it. Technology is the exploitation of such knowledge when a possible use for it has become

clear. To tell a scientist that he must only discover knowledge that can have beneficial and not harmful applications is like telling a miner that he must only quarry from the earth the kind of iron which is used for cutlery and bridges, and refrain from quarrying iron which might be used for guns. And to tell our pure scientists that they must apply their art to immediately useful ends is like a scheme to turn all our miners into blacksmiths—an excellent scheme were it not that we should presently run completely out of iron. I would apologise humbly for flogging a horse which ought to be so very dead, were it not that this particular horse so obstinately refuses to die. Let us then rid our minds of this confusion, and realise that the attacks are not attacks on science itself, but on the uses to which scientific knowledge is put. If science had not, by what one is tempted to call a secondary effect, this extraordinary importance in increasing the scope of technology, no one would be disquieted about it any more than they would have attacked music or art or literature in general as malevolent outbreaks of human activity.

I hope you agree with me then in interpreting our case as resting upon the question whether the enormous effect which science has had in increasing our technological achievement is a good or bad thing. The answer is one which depends upon what we believe to be good or bad. May I return to the prophecy, made earlier in this address, that the scientific and technological era on which we are entering marks a change from civilisation into a new unknown (x), which bears to civilisation the relation which civilisation has born to barbarism. I hope you will not have thought for a moment that I meant to imply that the conquest of material Nature is itself this new 'x.' It is not so, any more than growing corn constituted civilisation. But until man had his crops and so a regular store of food, settled communities were not possible, and until such communities existed it was not possible to have libraries, art galleries, concert halls, universities or cathedrals. The conquest of Nature is the foundation on which all these higher flights of human achievement are dependent for their support. The structure can be raised no higher than the foundations will stand, the spirit and body of mankind are so completely interdependent. Whether you believe this greater functional complexity to be a good thing depends on whether you believe it to be finer to compose a sonata for the piano or for a tom-tom. I have no doubt of the answer myself, but realise it is only an instinctive belief.

When I express my belief that the new era of control over Nature will be in a similar way the foundation of a new order of human existence and achievement, it is because I see in it a continuation of the same movement which turned barbarism into civilisation. Signs of it are the merging of smaller into larger units, of insurance against chance disasters, of better communications, of greater specialisation of function. The reality behind it is closer communion between men's minds in ever larger numbers. The new era brings bewildering complexities in its train. It is natural to long to escape back to a world in which our instincts and traditions served us so much better, just as a tired man seeks relief in a hunting and fishing holiday which turns him temporarily into a primitive savage, or by digging in his garden like a primitive agriculturist, but we must go forward.

I do not wish to belittle the individual triumphs of applied science which make it possible to combat some dread disease, to add a new interest to our lives, to provide men with better clothing, food or housing. We must, however, take a very long view indeed if we wish to see the real significance of what is happening to us at the present time. The great changes which are coming over all human relationships mark the beginning of a new adventure in living, a new medium with richer potentialities for the expression of human aspirations. We have been rightly warned of the folly of expecting something for nothing, as if the triumphs of technology were a series of presents to us which will usher in a new age without any effort on our part. We shall only get from them what we put into them. The conditions are so new that men have had little time as yet to adjust themselves to them, but their thrill lies in their promise of a fuller deeper and richer type of social existence.

CORRESPONDING SOCIETIES

1950 CONFERENCE OF DELEGATES

THE Conference of Delegates of Corresponding Societies was held in the main block of the Edgbaston buildings of the University of Birmingham on Thursday, August 31 and Monday, September 4, 1950. The sessions were attended by representatives of 35 Societies. Observers from other interested organisations were also present. Dr. E. A. R. Ennion, then Warden of Flatford Mill Field Study Centre, presided. The following is a report of the Conference of which Mr. Frank Edwards (Brighton and Hove Natural History Society) was Secretary.

Thursday, August 31, 1950

THE NATURALIST IN THE FIELD TODAY

by

DR. E. A. R. ENNION

PRESIDENT OF THE CONFERENCE OF DELEGATES

THE Conference of Delegates assembles once more under the patronage of the British Association here, at Birmingham, where it is my privilege to address you. My academic qualifications are less imposing than those of many of my predecessors. I am a field naturalist. The tang of a salting suits me better than an armchair in a study. But the fact that a field naturalist—no matter who—has been chosen for this high office is surely a good omen : for does it not imply that Field Science is fairly acknowledged in its own right—even by 'our tardy English nation ' which has at last contrived to set up a Nature Conservancy ?

It may well be a while yet before this becomes as effective an instrument as are similar organisations in other countries, in Holland or Switzerland, or the Wild Life Service of the United States, but at least it now exists here in embryo and is a potential check to those who stand against us. For there are many who would sweep away the few remaining heaths and swamps and tracts of natural woodland left, leaving us nothing but a stark denuded landscape—bare hedgeless fields ; valleys and downs ' improved ' beyond recognition ; straightened and almost empty watercourses. Much of this, and perhaps under present-day stringencies nearly all of it, may be sheer necessity : the more imperative it is, therefore, to look after what is left.

Just how effective conservation can become is largely in our hands. Reserves cannot be administered properly by remote control committees, whether of strictly scientific or of predominantly sentimental composition. Still less could reserves be supervised successfully from a window in Whitehall. Their ultimate safeguard lies in the studied care and vigilance of amateur field naturalists up and down the land. Are we ready—can we be made ready—to take this on? A member of a local field or scientific society ; a representative or one of the resident rank and file of a national preservation society ; a lone worker with no corporate affinities ; a sympathetic Local Authority or other public trustee—how far is he or she able—and by ' able ' I mean not merely willing but also competent—to take on this task ahead ?

This is the basic question I shall attempt to answer. But if I am to make my status clear, and so the origins of this Address, I must first inflict on you a brief—a very brief—biography : and then no more personal details until the end of it.

After leaving Cambridge I chose a medical rather than an academic career—it might be more truthful to say that medicine was chosen for me, for I always went my rounds with one eye on the patients and the other on the birds and beasts and flowers of the fields and waysides. I am not the first country doctor

who has done that ! So not until the last few years has it been possible to devote the whole of one's time and energies to Natural History ; and, in particular, to the devising of ways and means whereby the less expert among us irrespective of age, sex, background or calling, can learn more —and go on learning more—of the outdoor interests nearest to his or her heart.

For that in effect has been the problem I set myself as Warden of Flatford Mill, the first of the four field centres now being run by the Council for the Promotion of Field Studies, whose President, as most of you will know, is that great ecologist Sir A. G. Tansley, Chairman of the Nature Conservancy. In this past five or six years much has been learned—of the ways of men as well as of mice and all the other things we study—and the experimental stage is almost over. A new phase is soon to begin, but of that more presently. So here I am, a renegade country doctor, come to discuss with you the prospects of 'The Naturalist in the Field Today.'

It is usual—though not invariable—for a Presidential Address to deal in retrospect ; to pass down the long gallery of distinguished ancestors, recalling achievements here and there and then bringing the closing scores up to date by adding recent developments—an impressive sum whenever it includes the doings of the great amateur naturalists of the past. But it is a tale that has often been told and, while I am by no means unmindful of the debt we owe them, you will perhaps forgive me if I turn immediately to the present, to the changes and challenges of today and of the more immediate future, in so far as this can be foreseen.

There has been a steady rise, and in these last few post-war years a sharp rise, in the ' curve of opportunity ' open to the amateur field naturalist. There are many contributory factors : books and other publications ; lectures ; broadcasts ; films ; short day or weekend courses of various kinds and finally the possibility of staying at one of the many field stations now open to the amateur and studying one's subject on the spot with somebody at hand to interpret and advise. Let us look at these factors in turn.

First books—an avalanche of books—with their slimmer but sterner counterparts, the scientific memoirs, keys and papers.

Most of us still rely on the older authors for our authorities on what one might call the less popular fancies : Dixon for Mosses; Sladen for Humblebees ; Webb and Sillem for Woodlice ; Edwards or Saunders for Homoptera and Heteroptera respectively, and so forth. But for the more popular groups—Butterflies, Wild Flowers—and especially for Birds, an almost bewildering range of literature is now available. Some of it admittedly is better left unread, and some again is mere embroidery round sets of excellent but rather expensive coloured plates or photographs. But much of it is written in a way that can be readily understood by anyone willing to make the effort. One would need to be uncommonly difficult to please to go into a bookseller's with a pound to spend and come out again with nothing in one's pocket.

Keys like the Identification Handbooks issued recently by the Royal Entomological Society ; or those published by the Freshwater Biological Association on Corixids, Cladocera, or the Fresh- and Brackish-water Gastropods ; or those by the Linnean Society on the Bivalves, are intended for the more serious workers. Alongside reference books like the Monographs of the Ray Society they are indispensable for a student who wishes to specialise on a particular group of animals. The new Ross-Craig Drawings serve much the same purpose for plants. But, given the run of a good library, perhaps there has never been any great difficulty in obtaining the requisite books for the student who has progressed as far as this. The expert has always contrived to look after himself.

Far more significant is the modern range of books which helps to bridge the gap for those who seek more than superficial knowledge of a subject but who are not yet qualified to use the type of books of which I have just spoken. Two that come to mind at once are Eales's *Littoral Fauna of the British Isles* and Mellanby's *Animal Life in Fresh Water*. Compare these with their forerunners of fifty years ago—Furneaux's *Sea Shore* and his *Life in Ponds and Streams*—and you have the difference in a nutshell. Or compare Sandars's *Insect Book for the Pocket* with its more immediate ancestors. It is books like these that pave the way for

those of the *Wayside and Woodland*, the *New Naturalist* and the *Field Study* series.

In a similar way the Journals and Proceedings of learned societies are now joined by a shoal of lesser fry. Most of these present countryside or wild life topics in a casual way, the standards both of accuracy and of literary merit varying from page to page. If the ease with which they multiply is any guide there must be a ready demand for light reading of this kind. A few of them are of genuine service to the amateur naturalist but he is best served by one of the many Society publications : the Bulletin of the Amateur Entomologists ; that of the British Trust for Ornithology ; or the Wild Flower Society's Magazine, to name three out of the many that might have been named. Bulletins of this kind provide him with a regular and inexpensive means of keeping in touch with his fellows. New methods, new ideas, all manner of hints and useful bits of information get into circulation in this way, and members are often encouraged to study the less-known groups : grasshoppers, humblebees, gammarids, harvesters and sedges, all have been on the ' information wanted ' lists of the last few months.

Another valuable source of information —and occasionally even of inspiration—is the Natural History Society Report. This may vary from the 170-page publication of the London N.H.S. in its dark green jacket, packed from cover to cover with Sectional activities, to the three or four duplicated sheets of the smaller Field Clubs. The bias in favour of this or that branch of study shifts from one decade to another, or even, in the case of School Societies, from year to year, according to the lights of the presiding genius. Records of whatever happens to be in the ascendant for the time being will often be full and accurate—Roman Pottery ; Medieval Brasses ; Fungi ; Rotifers ; Parasitic Hymenoptera as the case may be. Much of this material may reappear in permanent form as a County List or as a reference book : Webb and Sillem's monograph on the Woodlice came out serially in the *Essex Naturalist*.

I do not think I can be accused of undue partiality when I claim that birds get the lion's share of space available in the majority of local N.H.S. reports (excluding those devoted almost entirely to archæology or antiquarian interests). There are large numbers of amateur ornithologists scattered up and down the country, many of whom are active and competent observers. Also the organisation behind them is fairly efficient : any unusual bird moving about the country soon finds a chain of watchers on its tracks—watchers not slayers nowadays, except for a few backsliders who have yet to see the error of their ways.

Watching, that is learning all you can about an animal's personality and way of life, rather than merely collecting, that is finding and putting something in a box with a label on, is by far the more satisfactory way of spending your time. It helps to account for the excess of those who watch birds over those who collect something else—though there is, of course, a Society that watches snails. It is high time that snails and other animals got their share of watching and due prominence in N.H.S. reports.

After books, lectures in one of their many forms, are the next most useful aid to the amateur naturalist. Throughout the winter months nearly every Natural History Society in the country has its own programme of talks and meetings, the majority of which afford an opportunity to the Society members of hearing people and learning facts outside the normal reach of their experience. I do not know exactly how many of these Societies there are—the pages of that invaluable *Directory of Natural History Societies* issued recently by the Amateur Entomologists' Society reveal an astonishingly large number—nor do I know just how many lectures each one has per season : but it cannot be far short of ten thousand lectures all told. Add to this another large group of lectures sponsored by University Extra-mural Boards ; Local Authorities ; Workmen's Education Associations ; Women's Institutes and similar bodies : the grand total of words spoken becomes astronomical.

A good many of these are probably very useful words because, firstly, the audience that listens to them is a voluntary one. You need not go unless you want to go. Secondly, the lecturer is almost always voluntary too : the number of professional natural history lecturers is relatively very small. He need not lecture unless he

wishes to and he does not expect an extravagant fee, although nowadays he may have to cover his out of pocket expenses. So you will usually have a lecturer who talks from sheer love of his subject to an audience that comes because it is genuinely interested in that subject too. And thirdly, there will very often be an opportunity to put a question ; or to meet the lecturer afterwards informally for a little while, when personal queries can be aired and answered. The ' brains trust ' and its variants grew out of this, whereby you go straight to the subsequent discussion without the risk of listening to the lecture first !

The amateur naturalist, therefore, scores over his academic brother who must needs sit through the lectures he is bidden to attend—not that they are tedious. Far from it. The student has expert opinion in every branch at his beck and call, and the actual technique of lecturing, whether in lecture theatre or parish hall, has improved tremendously in the last twenty-five years. Visual aids—epidiascopes, diascopes, projectors for strips or 16 mm. film, and many other devices—extend the basic ' visual aid ' of diagrams on a blackboard. And there is usually provision for displaying specimens or exhibits of various kinds. It may be a fully equipped demonstration bench, or it may be two rickety card-tables set aside by side on a squeaky platform. But the most spectacular improvement is in photography and its projection, culminating in the documentary type of film.

But not all films are good. So long as those who are responsible for making films require that the film's first duty is to attract and entertain, or even to instruct, so long shall we be denied the kind of film we want—the kind that presents facts with the least possible use of persuasion and artifice. Nature as seen through the eyes of Hollywood and Wardour Street is not the kind we know. The use of commercial nature films for primary schools and grown-up audiences whose interests lie elsewhere might be all to the good—an occasional convert may result—but they are seldom very profitable for the amateur naturalist. He will prefer his specialist film, with or without an accompanying lecture.

Much the same applies to broadcasting. Here it is the superficial or the ' Out with Romany ' type of programme which may gain a convert here and there—and no doubt stir up pleasant memories for many more who spend their leisure hours outdoors—but which cannot be said to make a serious contribution to the training of a naturalist. It is not intended to do this. Nor, except for certain specialised recordings, like Dr. Koch's bird song records, and a few of the Third Programme talks are we likely to be helped more : nature is not very amenable to the microphone. Perhaps in time we may get useful aids from television.

But *all* of them—books, lectures, films and radio—suffer from a fundamental weakness. The goods they seek to sell are second-hand. The reader or the listener or the film watcher is enjoying someone else's triumphs and experiences. It is only by his own exertions and discoveries that he will learn—in time—to become a naturalist. What are the opportunities for doing that ?

I can say at once that they are many times greater than even before the war—though still not nearly good enough where the ordinary mortal is concerned. He or she, that is, who is neither a student studying geology, botany or zoology at a university nor a fairly expert bird watcher. For these two groups the position is better.

The Marine Biological Laboratory at Plymouth was founded in 1884—twelve years after its famous predecessor at Naples. And it is a curious thing that, until quite recently, all the university-controlled outdoor research stations have followed suit and fallen for marine biology : Millport, Cullercoats, Port Erin, Robin Hood's Bay, Bangor—with the exception of the freshwater experts on Windermere. Together with a few vacancies for research students at the Ministry of Fisheries Laboratories at Lowestoft or Conway ; or the Scottish Board's at Aberdeen, there are now training facilities for about two hundred students at a time. But of these at least half will be long-term tenancies for post-graduates.

The remainder, i.e. about one hundred short-term vacancies for the several weeks of Easter and Long Vacation Courses, would seem to be sufficient to ensure that most second, if not first, year students get at least a little first-hand knowledge of marine or fresh-water biology. This potential capacity, incidentally, has been nearly

doubled by the Field Centres at Dale Fort, Flatford Mill and Malham Tarn, all of which now take their share of university students.

Perhaps this traditional bias towards Marine Biology is only to be expected of a nation that produced the voyages of the *Beagle* and the *Challenger* and the *Discovery*. In time the opportunities ashore may catch up with opportunities afloat. For latterly the universities have been turning their attention to things terrestrial too—to ecological research in a large way. Oxford, the home of the Bureau of Animal Populations and of the Edward Grey Institute, has got Wytham ; Imperial College has its Surrey station ; and now Cambridge has added the Madingley estates to its former charge of Wicken and Chippenham Fens. These, together with such research institutes as Rothamsted, East Malling, Aberystwith and other (primarily agricultural or veterinary) experimental stations, offer at least a few training facilities for advanced students. And, once more, the potential accommodation has been enlarged considerably by our four Field Centres.

So, in one way or another, the university student who seeks a short spell of field work in his or her own subject need not complain about lack of room or variety. The biggest obstacle is the reluctance of university chests to make grants in aid. But, apart from this, a university member is no better off than anyone else when it is a matter of wanting to study something outside the subject officially prescribed—if a botanist for example, felt that he (or she) would like to take a fortnight's course on insects to enlarge his (or her) scope. There might be a grant for more botany ; not for anything else.

And where would they go ?—unless, of course, they chose to study birds. The choice then would be ample, for there are at least sixty available berths to be filled for any given time ; and there will soon be more. The bird observatory on Skokholm Island off the Pembrokeshire coast was begun by what is now the West Wales Field Society in 1933. There are now seven of these observatories scattered round our coasts—Lundy, Spurn Head, Fair Isle and the Isle of May, Gibraltar Point and two in Norfolk, Scolt Head and Cley ; another inland at the New Grounds of the Severn Wildfowl Trust, and at least two more are getting under way : one, of a rather different kind, on the Northumbrian coast opposite the Farnes ; and another in the North-West. At only one of them, Skokholm, where groups from Cardiff University and other independent naturalists worked together to produce the symposium given before the British Association at Newcastle last year, at only one has any significant amount of work been done on anything other than birds—although, to be sure, there is no lack of enthusiasm and competence *here*. Ornithology is, of course the avowed and proper function of a bird observatory.

But the more one learns of birds, and of those who study birds (I see the better part of three hundred bird students a year at work outdoors for periods ranging from weekends to three weeks or so), the more one is impressed with the need for links with other sciences ; with field entomology and botany in particular, and with ecology in general. No ornithologist worth his salt denies the need for help from these kindred sciences. We look forward to the day when there will be a well established interchange of knowledge and mutual aid on a lend-lease basis.

But it is of no use merely wishing for things. It is necessary to be up and doing —hence the Field Centres we started five years ago. Well over fifteen thousand resident students have passed through them in this time.

This speaks for itself ; the need was there. And this was the first big step in the right direction. It was not necessarily the first step of all. The outdoor study group set up by the Misses Pugh at Stockbury, Kent, over twenty years ago was the immediate predecessor. Others may well have been working along similar lines though we had not heard of any. Francis Butler, in 1943, envisaged field study opportunities on what one might call a national scale, and Flatford Mill, which I had the privilege to plan and prepare, opened its doors in May 1946 to accept the amateur naturalist on a really large and comprehensive basis.

In spite of endless difficulties, financial and otherwise, and ridiculously inadequate equipment, four of these centres are

now running at full strength and taking between forty and fifty students a week from March to October, with a few coming during the winter—about fourteen hundred a year each, from all over the country and from many sources. Schools, training colleges and university students form the great majority, but we get a fair leavening of independent naturalists and artists.

On the teaching side, each is staffed by a Warden and an Assistant Warden who, between them, must be able to cover everything ; the Warden also being responsible for the entire organisation of his Centre. A few of the parties, particularly the University groups, are self-supporting. All of the others need help.

It is an exacting job but a very much alive one, and, looking back rather critically over the past five years, I think I can honestly say a worthwhile one. A very large number of young people (and quite a few older ones) have had an introduction to outdoor biology in its widest sense which they could never have got in any other way. They have seen and handled the plants and animals, the soils and water, the cattle and buildings that most of them had only read about hitherto. They have learned the rudiments of scientific method and have tried out most of the dodges used by the ecologist : transects, quadrats, counts and so forth. They have made maps, and they have used maps, and have been shown at least how to set about the identification of specimens brought home—be it ant or beetle, moss or Crucifer, bird or fossil or Regency fan-light.

Above all else, in spite of long hours and long trudging, they enjoy it, if the high proportion of those who come back for more is any criterion. We passed the thousand mark for this season at Flatford Mill several weeks ago : over two hundred of these students had been there before. That is the most telling evidence on which I base my claim that starting these field centres has been worthwhile. For it means that some at least of the many who come to us have been well and truly bitten. They come back again and again. The tragedy is that one can do so little for them with all the multifarious claims upon one's time.

But it is neither my business nor my intention to discuss the Council's policy. If we are to retain some measure of autonomy these Centres must pay their way, and we shall continue to accept large numbers of unselected students, sifting out future naturalists as best we can. This indeed is a not unworthy function quite apart from the hope that the larger the numbers the greater the chances of discovering hidden talent. There is no shadow of doubt but that a week spent in this way—outdoors and hard at work in eager, infectious company, free for six whole days from the triple scourge of newspapers, radio and cinema :—there is no doubt that a week spent in this way makes for swift understanding between student and teacher (it would be nearer the truth to say learners together). If virtue is there, it will out.

So we may assume that, in any one year, about one thousand University members come to stay at the Field Centres ; together with about five hundred older independent visitors—artists, research students or naturalists who have served their apprenticeship. This leaves rather more than four thousand vacancies a year, distributed among the four Centres, to be taken up by teachers, training college students, Sixth form boys and girls and others whose previous experience of outdoor biology or geography is almost nil. An opportunity, that is, for four thousand novices a year to be introduced to field work at the beginning of their careers.

This is better than nothing ; but when I tell you that for one Spring Biology Course alone I had applications to send small parties from over thirty different schools, it is clear that the amateur naturalist is not overburdened with opportunities. We hope, of course, that these Centres will expand : not in size individually, for fifty students at a time is all that one stretch of countryside should be asked to stand—and rather more than one Warden plus his Assistant can comfortably command—but in numbers. A dozen of them spread over the country on well chosen ground would supply the theoretical demand.

So the naturalist in the field today, whether novice or old hand, can claim that he or she is much better off than in the days before the war. There is somewhere to go with expert help at hand. There is room for the university student ;

room for the ornithologist; room (although not yet enough) for the average school or training college student.

But there is no adequate provision for the boy or girl, or for the man or woman—for the one in every twenty-five or so—who takes to field work like a duck to water once the way has been shown. For those, in other words, who would repay a thousand-fold a little individual attention. It is well-nigh hopeless to expect this in the scramble of a Centre in full swing—my day already begins at six and ends at half past ten!—and yet these people, our future parsons and lawyers, soldiers and sailors, doctors and nurses, farmers and traders—the amateur naturalists of tomorrow—are of prime importance. For I need scarcely remind you that amateur naturalists are, and always have been, the salt of the earth. Something must be done for them. They need arrangements of a rather different kind—somewhere where they know they will always be welcomed individually.

Monks' House on the Northumberland coast has been secured for this purpose. It lies just south of Bamburgh, opposite the Farnes. It is the site used by the monks of Holy Island in the seventh century—St. Aidan and St. Cuthbert and their brethren—for ferrying to and from their retreat on the Inner Farne, half a mile offshore. It will be open next Easter, and be intermediate in size, and also to some extent in character, between the large Field Centres of the C.P.F.S. and the smaller Bird Observatories. It is designed expressly for the amateur field naturalist; primarily perhaps for the field ornithologist since, of all field workers, he is the most numerous and, on the average, the most competent.

But there will be plenty of room and opportunity for others: the Border Castles and the Great Whin Sill; a first-rate coastline for marine work; moorland and dunes for the plant ecologist, backed by the strong blue skyline of Kyloe and Cheviot. It was not chosen without looking around well first.

Twenty-five, perhaps occasionally thirty, students in residence at a time will be the maximum number taken; but far more often the limit will be fifteen or less. This will enable me as Director, to get to know them individually and well; to help them as they should be helped; to offer the right blend of caution and encouragement when and where it is needed most; to hearten the waverers and bring the careless ones to book.

We hope that when the British Association meets at Edinburgh next year, some of you will find the time to cross the Border and visit Monks' House, the next step in this great experiment.

At the close of the Address there was discussion in which reference was made to the following points: The work of regional Unions of Scientific Societies; should a Union's Headquarters be a field centre; Union annual meetings poorly attended when not at seaside; attendance at Field Study Centres from distance rather than local; Field Centres and control of Nature Conservancy; Field Study Centre Committee of local people includes representatives of the local Natural History Society; could each Union establish own Field Centre; cost of running a Field Centre considerable; would Government Grants be available; records of field work kept by students and transmitted to various Museums, etc.

After tea in the University Refectory delegates saw three films: *This was England*, a record of traditional crafts in a Suffolk area; *Woodlands*, the geological basis of oak and beech woods; and *The Buzzard*, a film made on the Welsh coast.

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The second session began with an address on National Parks by Sir Patrick Duff, K.C.B., K.C.V.O., Chairman of the National Parks Commission. He said that in spite of the goodwill with which the scheme for National Parks had been launched there was much vagueness and misunderstanding as to what exactly constituted a National Park and what its purpose was. The 'Parks' might be as large as 800 square miles, spread over several counties. They were 'National' only in the sense that the whole country had an interest in keeping them unspoiled and that national funds might be made available for them. The land would not in any sense become public property nor would it be thrown open without restriction. The purpose of National Parks was twofold: that the characteristic beauty of the landscape should be preserved; and that the visiting public should have ample access for recreation

and the enjoyment of its beauty. All the normal utilitarian activities essential to the country's economy must go on, but their development would be controlled. Sir Patrick listed the twelve districts so far designated. Between them they covered one-tenth of the area of England and Wales. In spite of the difficulties of consulting all the authorities concerned (26 in the case of one Park) it was hoped to have the boundaries of three defined by the end of the year : Lake District, Peak District and Snowdonia. Sir Patrick also described the arrangements for administering the Parks. Joint local planning authorities would be responsible : not the Commission, which would be advisory. The latter part of the Address was concerned with codes of conduct for as Sir Patrick put it : ' The process of preparing the Parks for the people requires the complementary process of preparing the people for the Parks.'

At the end of the Address the meeting was thrown open for discussion. Sir Patrick Duff dealt with the various points raised. They included : codes of conduct for the farmer in a National Park area ; codes of behaviour for the walker ; County Council sign-posting of footpaths ; the dumping of industrial debris in places where geological sections would be thus buried ; the needs of each National Park area for assistance by local societies, including fighting against disfigurement ; the draining of fields in the Lymington area.

After tea, which was served in the University Refectory to about 40 delegates, there was a session on museums.

Professor H. R. Hewer of Imperial College opened the session with a talk on ' Museums and the Community.' He described museums, both national and local, as places where collections of objects were gathered together and studied. The work of museums consisted of three main things, viz. research, identification and display. So far as the public were concerned, i.e. all except museum staff, the object of the museum should be to satisfy the minority which delighted in museums and to attract as many as possible of the majority ranging from those who were interested but easily deterred to those who were bored by any intellectual activity. Speaking of local museums, Professor Hewer said he would like to see them all performing the three functions he had mentioned. Research should be undertaken by staff and by local amateurs. Identification might be difficult but groups of museums might collaborate through the Museums' Association. Display should be closely linked with local interests but should not be too parochial. Some difficulties of local museums might be overcome if help were given by local scientific societies. In many cases the assistance would be of mutual advantage for, in helping museums to enrich the lives of the community they served, societies would be brought into contact with potential members.

Professor Hewer was followed by Mr. R. Merrifield, Assistant Curator of the Guildhall Museum, London, who spoke on ' The Local Museum and the Local Society.'

He said that the ideal relationship between a local society and the local museum was one in which there was recognition of identity of interest in research work and in preservation of documented collections, in which the educational work of the museum was valued by the society both for its own sake and as a useful link with the general public. This sympathy should find expression in co-operation and mutual assistance. In the past many local societies founded their own museums and the best of these had developed an independent life, with financial aid from local authorities or universities. The upkeep of a good museum being now so expensive there were few societies able to maintain their own. The continued maintenance of a neglected and moribund museum could only bring discredit. Transfer to public ownership and adequate financial support was desirable as soon as a museum was ready to play a full part in the education and enlightenment of the community. Where museums did not exist, societies could act as pressure groups to have them established. Any museum embarking on an active educational policy, or attempting to stimulate the interest of non-specialists, must divide its collection into two parts, a smaller part occupying the greater amount of space, displayed to catch the interest of the general public, and a larger part not usually seen by the visitor but available for the student and research worker. Local societies could help with both parts but especially the latter, for their amateur specialist members would be able to help the professional curator with wide responsibilities to identify, classify and display. Mr. Merrifield also spoke about the possibility of arranging for members of societies to form a panel to supplement exhibitions with conducted tours and popular talks.

Some general discussion followed the two papers. The speakers included Miss Morris (Warwick County Museum), who spoke about the use of dioramas (constructed by members of local societies) which could be changed at frequent intervals at no expense to the museum. Dr. W. Campbell Smith (Keeper of Geology, British Museum of Natural History) also spoke to this point and Mr. D. B. Harden (representing the Museums' Association) said that the problem of finance was the greatest difficulty facing museums' staff at the present time.

PROBLEMS OF POST-WAR FORESTRY[1]

by

LORD BOLTON

I MUST begin with two apologies. The first is in regard to the title of my paper. I mean to use some of the problems which confront the foresters of this post-war period as so many pegs on which to hang the suggestions I want to put before you, so it may be you will think that I am rather wandering from the point from time to time. The second apology is for the fact that I may make frequent references to my own woods. That will not be out of conceit, but because it is so much easier to be lucid and convincing when quoting a real example than by inventing a theoretical one.

Now for the effects of two world wars upon our forestry practice and economics —effects both good and bad. At first glance it may seem ridiculous to suggest that war may have had any effects on forestry that were not wholly bad, but I think it is quite likely that a historian of forestry a hundred years hence would say unhesitatingly that the two world wars were factors for good in the advancement of English forestry to a greater degree than any other event in our history to date.

That is, perhaps, more easily understood if you look at the picture from the same angle as Toynbee regarded civilisation in his *Study of History*. His argument is that civilisation, or nations or individuals, makes little or no forward progress in times of ease and plenty. When progress is made at all it is made in times of trouble. Alternatively, as he puts it, civilisation and the units comprising it are subjected to a challenge, and if their response is a brave one then forward and upward progress is made. Now judge forestry according to that theory. We can look on the period between the industrial revolution and 1913 as the period of ease and plenty, and we must all admit to our shame that, so far as English forestry was concerned, Toynbee's theory was right. During all that time—the best part of a hundred years—forestry stagnated and, apart from the slowly growing interest aroused by the Forestry Societies, any progress that was made was trivial. Then came the war of 1914–18, the first challenge.

What was our response? Up to then forestry had been a Cinderella, an unrecognised science, a neglected industry. The war brought home to those in authority a recognition—which was to prove lasting —of the vital and essential importance of our woodlands to the very existence of Britain as a nation. It brought home to them too, the bitter knowledge that our woodlands were producing only a fraction of what they might do, and that their extent was totally inadequate for our needs. This recognition, as I have said, proved lasting, and it resulted in the formation of the Forestry Commission, charged with the establishment of vast new forests and the improvement of existing woodlands, whether publicly or privately owned.

Surely that response—the recognition of forestry as an industry of the first importance and the formation of a Forestry Authority—was a tremendous stride forward, the beneficial effects of which can hardly be exaggerated and which far outweighs the evils of over-felling, devastation with consequent reduction of increment, and disorganisation of the economics of forest management. Those evils were very great, but they were after all, temporary. The good results are a permanency of immeasurable benefit, not only to ourselves but to those, too, who will come after us.

But still the lesson was not fully learned. During the inter-war years the building up of the State forests proceeded apace, but no very serious efforts, apart from the

[1] Chairman's Address to the Forestry Subsection, at Birmingham, on September 4, 1950.

planting grants, were made to vitalise privately owned woodlands. Only the Forestry Societies persisted in their efforts to arouse enthusiasm and spread knowledge.

Then came the second war, so infinitely more serious in its ill effects of devastation and over-felling and all the various difficulties and problems proceeding from them. But this second challenge, too, had its response.

In 1939 the newly formed forests of the Forestry Commission were still for the most part too young to make any considerable contribution to the national timber requirements though they yielded increasing quantities of pitwood as the war proceeded. So it was that, for the second time in twenty-five years, the main burden of the sacrifice fell on private woodlands, and they provided the bulk of the home-produced timber from 1939–45.

The response to this second challenge was recognition of the fact that private woodlands are of as much importance to the existence and economics of our country as the State forests and, following on this, the drawing up of a carefully thought out scheme for their improvement which holds great promise of success.

Surely this again outweighs the temporary disasters of wholesale devastation, calamitous though it is for foresters of the present day. At long last forestry, both State and private, is established in the forefront of the national picture.

Now for the problems, and I would say at once that, while their solution would appear at first so obvious as not to merit discussion I shall try to show that is not easy to find the right answer.

The first problem then, is the rate at which we should try to make good our war fellings by replanting. The obvious reply to that is—replant your woodlands as quickly as you possibly can. If you can catch up with your arrears within a year or two then do so, and in any case you should have made good all your war fellings within say six or seven years of the end of the war.

Is that the right answer? I think not. In favour of a rapid rate of replanting there are two arguments, and I think only two. The first is that the longer land is left unplanted the worse will be the weed growth and the more expensive the replanting. The other is that the sooner land is replanted the sooner it will be producing timber to the profit of the owner and the country at large. Both these arguments are of course, unanswerable, and if they stood by themselves would solve the problem.

But now look at the other side of the picture, and to give it clearly I am going to refer to my own estate. Of the five hundred acres or so of nominal woodland nearly two hundred were felled during the war. I have a woodland staff of eight men and just think for a moment what would be the consequences were I to replant the whole of the two hundred acres within say, a five-year period. To begin with this would mean an annual replanting programme of forty acres, and though my staff could tackle this it would be to the almost total exclusion of any thinning of existing plantations or the carrying out of any other winter work. Next, and more serious still, my plantations for the most part require summer cleaning of weeds for the first three years, so we would be faced with a hundred and twenty acres to be cleaned by eight men—an impossible task unless we started cleaning weeks before it was really necessary and continued weeks after it was overdue. In other words a big proportion of the plantations would suffer injury and quite a lot of the money expended on planting would be wasted.

The next result would be that in twelve or fifteen years a disproportionately large acreage of plantations would fall due for thinning simultaneously with the probable consequence that some part of them would be under thinned. Worse still, however, and this is perhaps the most serious effect of all, our supply of thinnings which we put on the market would be irregular to say the least of it. For a few years we would, comparatively speaking, flood the market, after which we would have a dearth of thinnings. It cannot be too strongly emphasised that a steady and regular flow of thinnings onto the market year after year, an assured supply for the buyers, is the whole secret of successful marketing of small produce, and for this reason, together with the other reasons that I have put forward, I feel that over-enthusiasm for a high rate of replanting is

a mistake. Surely, too, it is far more important for the welfare of the woodlands and far more speedily productive of an increased rate of increment to give thinning of existing plantations priority over replanting and, indeed, over every other forest operation.

The policy that I am trying to carry out is as follows. Since replanting began again after the war I have been replanting at the rate of ten acres a year, which is normal for the woodlands, and have concentrated the labour force on catching up with arrears of thinnings. Last year we increased our replanting rate to fifteen acres a year, and it may be that in two, three or four years' time, when we really are up to date with our thinning programme, we will be able to increase the rate still further. But we are quite determined that thinning must always have high priority over every other forest operation.

So much for the problems of the rate of replanting. Now for the problem of the choice of species. I imagine that very many people if asked how to determine the species of tree to plant would say that the species selected should, first and foremost, be perfectly suited to the soil and situation, and secondly that it should be the most valuable financially of the suitable species. Both these reasons are of course, obviously correct, but I think that there is another one of even greater importance, which is all too often ignored, and that is the precept that the species chosen—or rather the mixture of species chosen—must be such that, under the proposed crop, the soil will improve, or at the worst will not deteriorate. After all, if one takes the parallel example of agriculture, one does not judge the standard of a tenant farmer by the mount of money he makes, for quite often the worst farmers have the largest bank balances. He is judged by the way he treats his land, by whether or not he puts more into it than he takes out, above all, by whether, under his care, the soil is improving or deteriorating. So it should surely be in the case of forestry, and the responsibility of the forester is all the greater for the very fact that the results of his good or bad choice may not become evident for years to come. I would suggest—and I am very well aware that I am on controversial ground—that the first essential of soil improvement is never to plant large blocks of any coniferous species pure, but always to have an admixture of hardwoods, even if the proportion has for some reason to be as low as five per cent. I believe this is important for soil which is in good heart in order to prevent deterioration, and I believe it to be of equal importance in the case of poor or acid land, not only to prevent deterioration but also to lead to improvement. After all, it is surely a policy of defeatism to plant say, a mass of pure Sitka, knowing that at maturity the soil may be left not even fit for Sitka, whereas the admixture of a very few hardwoods might make it safe for a further rotation, not for Sitka only, but, perhaps, for some more valuable species.

The next problem is when is a forester justified in recommencing a system of annual clearfalls and replanting which is, of course, a fundamental necessity for profitable commercial forestry. I am going to ignore two external factors which are out of the forester's control, namely the curtailment of felling order which severely limits his powers to have a clearfall at all, and Sir Stafford Cripps who makes it well-nigh impossible for him to avoid having very extensive clearfalls at very frequent intervals.

But what, apart from these, are the considerations which should govern a forester's decision as to when he should resume clear-felling? I think that there are several of them. In the first place he should avoid having any clearfalls until he has come within measurable distance of catching up with the replanting of his war-devastated areas. That is self-evident. Even when he does clearfell, the area felled annually should be less than the area replanted until he has caught right up with his arrears.

Next, the volume of timber he is justified in felling must be governed by the annual rate of increment over his total woodland area, and, here again, the volume felled should be below the increment figure until the annual increment figure regains normality. On my own estate of five hundred acres the annual increment figure should be in the neighbourhood of 40,000–50,000 cubic feet, but owing to war fellings of half a million

cubic feet, and owing to neglect of thinning in the past, the rate of increment in 1945 was around the pitiable figure of 7,000 cubic feet. Today it is probably about 16,000 cubic feet but it would obviously be wrong for me to have a clearfall of anything approaching that figure, and I would prefer to avoid having any considerable clearfall until the increment is well above 30,000 cubic feet.

The last subject I want to touch on is the question of thinning. I suppose it could be readily agreed that many plantations are underthinned and that an overthinned one is a considerable rarity. I want, however, to suggest that in the case of many, perhaps most, species even the accepted rates of thinning are too low, and that we should attain final spacing of our crops very much earlier than we have done hithero. I refer more particularly to hardwoods though I believe it applies to many softwoods, too, and my reason is largely a financial one. Consider for a moment what happens under the accepted thinning methods. Thinning continues until within a few years of maturity and, in the case of the longer rotation species, is still continuing at and after the fiftieth year. But the vigorous rate of growth of all, or nearly all species begins to slacken off by about the fiftieth year, so that a great deal of that vigour is devoted to height growth at the expense of girth. One effect of that, in the case of species which must attain a large girth if they are to secure maximum prices, is that an unduly long rotation is necessary. Sycamore for instance, which must have a quarter girth of eighteen and a half inches and upwards to command a really high price, requires a rotation of eighty-five to one hundred years. Present methods produce a wood which is a joy to see, with clean boles of forty, fifty and sixty feet, but I strongly question whether that is financially desirable, because with a few exceptions, such as ash for certain special requirements, what is wanted in hardwoods is girth not length, and I believe that a maximum bole of thirty feet should be aimed at; one should be contented with a bole of twenty-five feet, and not dissatisfied with one of twenty feet. If that is accepted then I believe we can attain our objective under a very much shorter rotation than is possible with present thinning methods and with, of course, greatly enhanced financial returns as a result.

I should like to describe how we are trying to do this in the case of sycamore. We are basing our method on two facts. The first, which has been confirmed by several merchants, that twenty-five feet is an ample length of bole. The second that the most profitable returns from sycamore thinnings are from trees of three to six inches diameter. Bearing that in mind we propose to determine those trees which are to form our final crop at the time of the first thinning, and we will, as it were, thin away from them. Any trees which are actively competing with or damaging a final crop tree must of course, come out at once, the remainder will be removed as and when they attain six inches in diameter. The result, as I judge it, should be that we will attain final spacing by the twenty-fifth, or at latest the thirtieth year. As sycamore average two feet or more in height growth during the first thirty years, the trees forming the final crop will by that time be fifty to sixty feet high, and it should be very easy to ensure, partly by natural methods, partly by pruning, that they have a clean bole of twenty-five feet. That bole with its larger crown to feed it, and furthermore, with twenty to twenty-five years of full vigour before the fiftieth year is reached, must surely attain the necessary quarter girth very many years earlier than would ordinarily be the case. Judging by the growth of certain individual trees the rotation might well be reduced to sixty or seventy years instead of eighty-five to one hundred years. The effect on the financial returns from the woodlands if that supposition is correct needs no underlining.

THE CRITICAL IMPORTANCE OF HIGHER TECHNOLOGICAL EDUCATION IN RELATION TO PRODUCTIVITY[1]

by

SIR EWART SMITH

SINCE the end of the war, it has frequently been pointed out that this country still occupies a foremost place in the production of fresh knowledge as a result of research, but that in general it appears to be falling behind some other industrial nations in applying such knowledge to productive purposes.

During this same period, the economic position has also forced attention to the supreme importance of industrial productivity. There is obviously a strong connection between the subjects of industrial efficiency and the supply of manpower trained, and used, to apply the evergrowing mass of scientific knowledge to productive ends.

There has been much recent discussion on the urgent need to extend higher technological education in order to improve this position, and in comparison with the inter-war years the output from the universities of scientific and technical personnel has been doubled. There now appears to be a belief in many directions, not least on the part of those responsible for university education, that this increase has gone far to fill the need for 'applied scientists' and that no extensive plans need now be made for a continuing increase.

The main purpose of this paper is to examine the relation between these subjects. Such an analysis can by its very nature only be made in broad terms and on a comparative basis. Special attention is paid, therefore, to relative rates of change, rather than to absolute values.

It is concluded that the national interest demands a further and *steadily continuing expansion* of facilities for training in the applied sciences, and particularly to graduate and post graduate level. Of these sciences, engineering and related technologies are much the most important as they are the main basis for the conversion of scientific knowledge to effective use in every type of industry.

Post-war conditions have made it abundantly clear that the economic position of this country depends primarily on the progress and efficiency of its industrial output. There is a general expectation that the standard of life should steadily improve on past standards, and there is, too, the tendency for the population as a whole to expect conditions of life (real wages) not less favourable than those in other leading industrial countries. The growing universality of press, radio and the cinema inevitably foster comparisons and desires of this kind.

It is pertinent, therefore, to examine what the trend of our own progress has been and also to compare this with the corresponding changes in other countries. It is natural to select first the United States for such a comparison, as that country has now taken over the dominant position in the industrial field which Great Britain at one time held. This is not to suggest that we should blindly follow that country, whether in educational methods, industrial practice or anything else—for those who merely copy must always be at least a stage behind. On the other hand, a critical examination of long term basic trends should be helpful in determining likely avenues of progress.

Such a broad analysis of industrial productivity for the United States and this country shows that, although the output

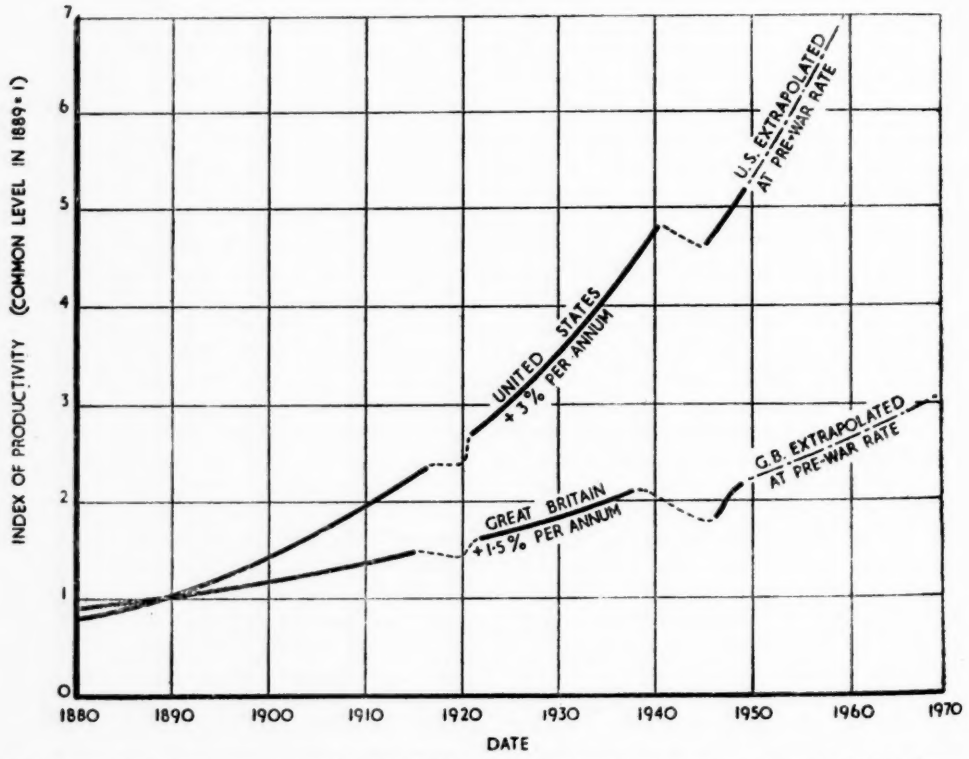
[1] Paper given to Section L (Education) at Birmingham on September 4, 1950.

per head was approximately equal just before the turn of the century, the United States has increased at approximately 3 per cent. per annum (at a compound interest rate), whereas in this country the annual rate has been almost exactly half that figure. As a result of this difference, United States industry has now an overall productivity per head of those engaged in it of approximately $2\frac{1}{2}$ times the corresponding figure in Great Britain. Although precise data are sparse for the earlier years, all the evidence supports this relative trend. (Diagram 1.)

Productivity in this comprehensive sense is, of course, used with reference to the average annual volume of output per head of all industrial employees, irrespective of type and grade. It must not be confused with a measurement of human physical effort, which is steadily decreasing with shorter hours and longer holidays and with the growing use of machinery to save manual toil. It is the resultant of all the factors which affect industrial output relative to the numbers involved. As such, it is the chief governing factor with regard to the economic progress and standard of living of an industrial nation such as our own, provided the total numbers in industry remain a more or less constant proportion of the population as a whole.

This difference in productivity which has developed during the past half-century is, in fact, the basic reason for the economic unbalance between the two countries. The effect of the war in reducing our foreign investments and in preventing the necessary replacement and

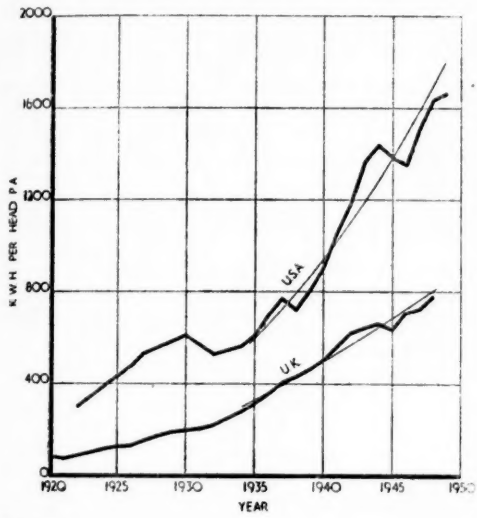
DIAGRAM 1. INDICES OF INDUSTRIAL PRODUCTIVITY (OUTPUT/MAN YEAR) FOR GREAT BRITAIN AND THE UNITED STATES.



Data drawn from many sources, such as the British and American Census of Production ; British Annual Abstract of Statistics ; the Economist ; papers by L. Orde and L. Rostas, etc. Where such data refers to hourly output, suitable corrections have been made to allow for the reduction in hours of work since the earlier years of the Survey. Information with regard to the first 40 years covered is very sparse but it is believed that the general trend shown by the curves is in broad general agreement with the facts.

improvement of our plant and equipment, has intensified our difficulties, but these difficulties were already developing before 1939 and would, quite apart from the war, have become increasingly apparent as the productivity of the two countries steadily diverged.

DIAGRAM 2. TOTAL ELECTRICITY SALES. COMPARISON OF U.K. AND U.S.A.



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As an alternative to examining productivity, it is pertinent to assess industrial progress in terms of the total output of goods or services per head of the population as a whole. Such a comparison between Great Britain and the United States, made product by product, or service by service, gives results which are generally similar in each case. The American output is usually somewhere between 1½ and 3 times the British with a long term rate of increase tending to maintain this lead.

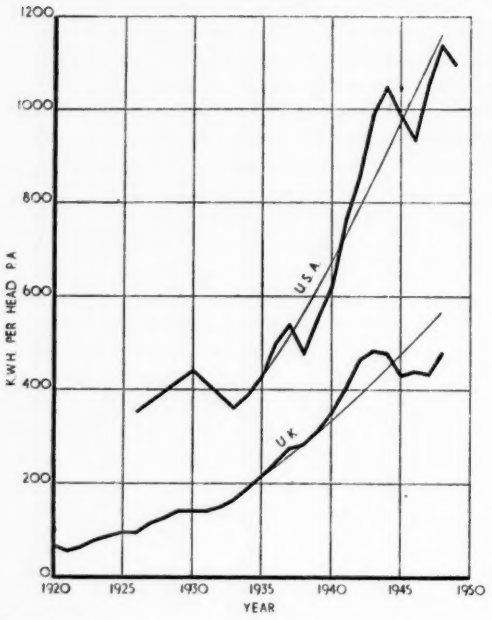
The data shown in Diagrams 2, 3, 4 and 5 give a number of typical examples and clearly illustrate this position. The long term trends of steel production and of usage of electricity for industrial purposes are particularly pertinent in view of their basic importance to all forms of industrial production.

In certain quarters, much has been made of our progress since the 1937–38 period, but the long term trends put this movement in its proper perspective and show that on the average it is no better than the previous performance. Having regard to war and post-war conditions, this may be considered a good achievement, but it is obvious how much more remains to be done if our *relative* position is not to deteriorate further. The most recent official figures issued by the Statistical Office of the United Nations show, for example, that between 1937 and 1949, the index of general industrial production increased from 100 to 156 in the United States and from 100 to 116 in the United Kingdom, i.e. by 35 per cent. and 9 per cent. respectively over the twelve years when corrected for the changes in population.

Those who are satisfied with our present condition may find the foregoing statement too wide and sweeping for ready acceptance. Within the scope of this paper, it is impossible to consider every aspect in detail, but all the knowledge which is accumulating, including that from the various missions of the Anglo-American Productivity Council, supports the general thesis which is put forward.

The reasons for the difference in the long term trends of increase in America and Great Britain are no doubt complex, but it will probably be agreed that the British industrial employee (whatever his function) is not behind his American counterpart in innate ability or in energy, provided that he has proper training, incentives (material and psychological) and leadership. Equally, it can be agreed that we are not behindhand in the production of fresh fundamental knowledge as a result of research and invention ; in any event, such knowledge, even in the short run, is normally available to all countries from whatever source it may arise. Under the heading of natural

DIAGRAM 3. INDUSTRIAL ELECTRICITY SALES. COMPARISON OF U.K. AND U.S.A.



Sources :

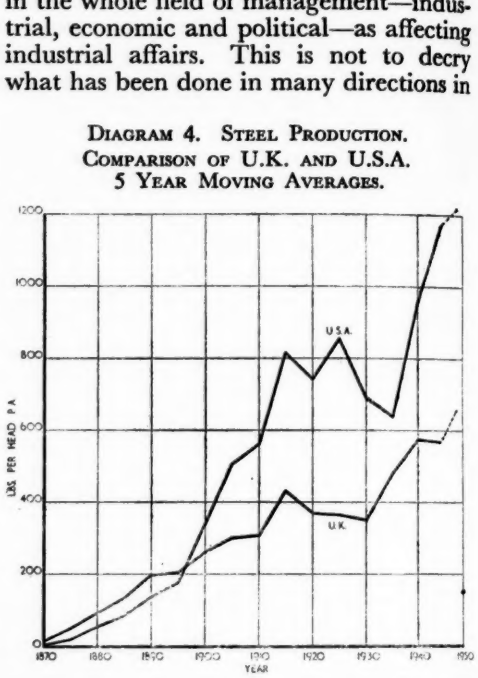
U.K. Statistical Abstract for the United Kingdom 1913 and 1924 to 1937.
Annual Abstract of Statistics. No. 84, 1935–46. No. 86, 1938–48.
British Electricity Authority. First Report and Accounts (August 1947 to March 1949) 1950.

U.S.A. Statistical Abstract of the United States. 1932–1948.
U.S. Department of Commerce. Survey of Current Business 1949–50.
Monthly Bulletin of Statistics. Statistical Office of the United Nations. July 1950.

resources or geographical facilities, this country may be worse off in some respects, but it has very definite advantages in others, and in any case essential raw materials and services can be obtained by any country prepared and able to pay the economic price (e.g. Switzerland has a very flourishing engineering industry although entirely without any indigenous supply of the necessary raw materials).

There is, however, one basic and controllable factor in which Great Britain and the United States differ from each other, *namely, in the relative numbers of those trained in applied science.* It is the writer's belief that our inferiority in this respect has not only slowed up the rate and efficiency with which scientific and technological knowledge is now being applied throughout industry in this country, but has also led to a lower overall standard of scientific approach and understanding in the whole field of management—industrial, economic and political—as affecting industrial affairs. This is not to decry what has been done in many directions in

DIAGRAM 4. STEEL PRODUCTION. COMPARISON OF U.K. AND U.S.A. 5 YEAR MOVING AVERAGES.



Sources :

Statistical Abstract for the United Kingdom 1913 and 1924 to 1937.
Annual Abstract of Statistics. No. 84, 1935–1946. No. 86, 1938–48.
Statistical Abstract of the United States. 1932–48.
U.S. Department of Commerce. Survey of Current Business 1949–50.
Monthly Bulletin of Statistics. Statistical Office of the United Nations. July 1950.
Iron and Steel in Britain, 1870–1930. By T. H. Burnham and G. O. Hoskins.

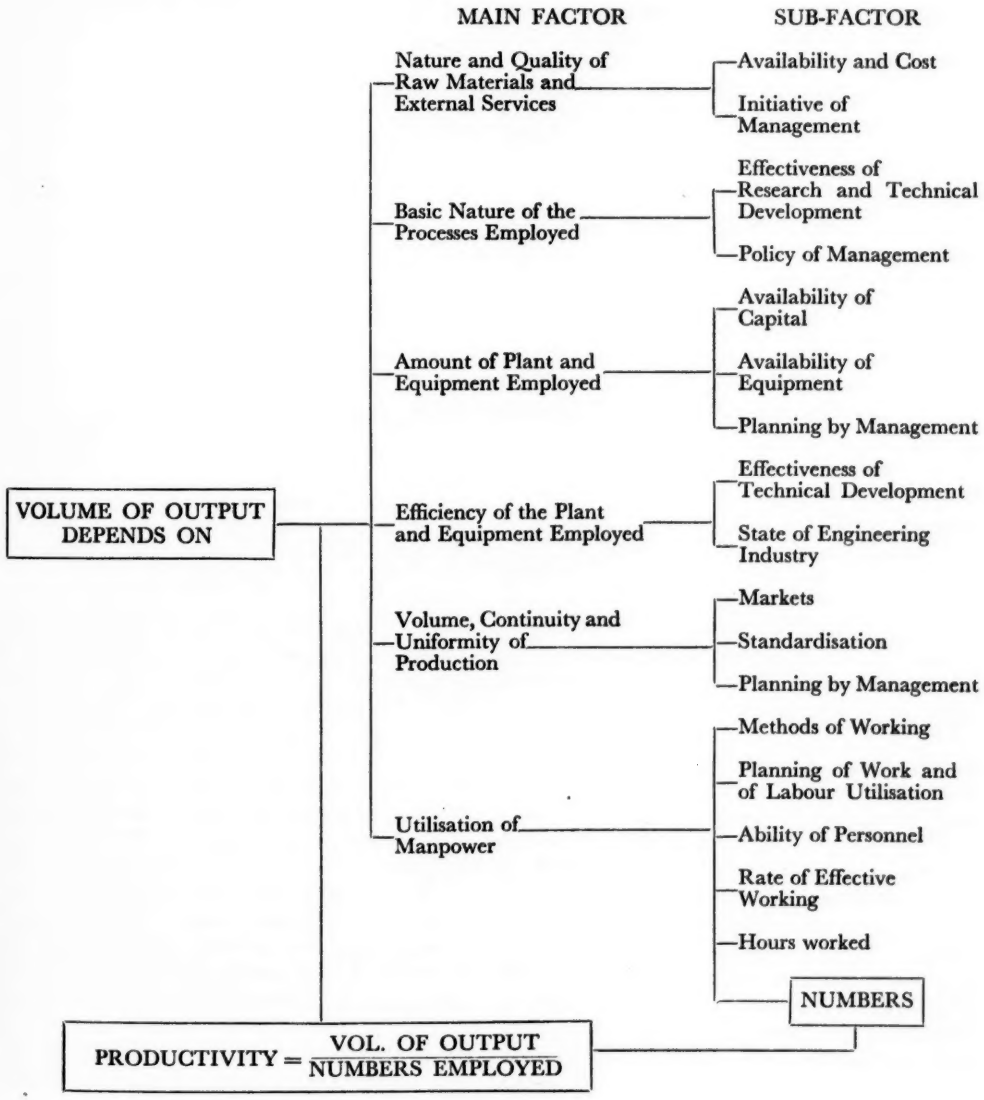
Note :

Owing to the fluctuations caused by the two world wars and by the depression of 1930–33, it is difficult to determine exact figures for the compound interest rate of change. Since 1900, however, this rate has been approximately 2·4 per cent. per annum in the U.S. and 1·4 per cent. per annum in the U.K. Having regard to the major importance of steel in relation to industrial activity of all kinds, the close similarity of these figures to those given in Diagram 1 for the change in productivity of the two countries is worthy of note. It will also be seen that the point at which the American production per capita exceeded that of the U.K. is in close accord with the period at which there was a corresponding change in the relative productivity.

the technical sphere. Indeed, having regard to the relatively small numbers of trained men this has in many ways been remarkable, and there is no reason to suppose that there has been any decline in the natural genius of the British race in engineering and other applied sciences. For example, in aeronautics, it might well be claimed that Great Britain has not only demonstrated its power to compete with any other country, but in many respects to lead the advance in this field. It must be remembered, however, that such progress has only been possible because this relatively new industry has from the outset appreciated the necessity for training and employing a very large number of first class technologists.

It may be helpful to repeat in part a previously published analysis of the fundamental factors governing productivity :

It is believed that the six main factors listed are those which control industrial efficiency, and all of them, in effect, depend in a major degree on the soundness of the technical approach and the ability of management. Even the two sub-factors which relate directly to human



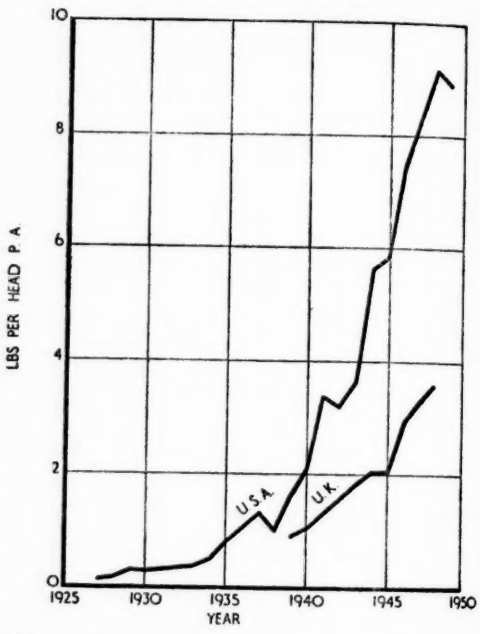
effort, are, in the long run, mainly affected by the extent to which the community as a whole understands the real basis of industrial progress, and appreciates the background of the technical, economic and psychological forces which come into play. There must not only be a wish for progress and a higher standard of life, but an active realisation of what is necessary to achieve it. The alternatives are force and totalitarianism on the one hand, or on the other, relative industrial and economic decline.

This general argument may be expressed in another way. Of all the factors which can influence productivity, the possibility of a continuing and unlimited increase depend on : (*a*) improvements in the basic processes employed, (*b*) an increase in the quantity of the plant and machinery used, and (*c*) improvement in its technical efficiency. That is to say, that for any given level of human energy and ability, the rate at which productivity will increase depends primarily upon the evolution and application of new technical knowledge. This, in turn, depends upon the numbers and quality of the technologists available, upon the ability of industry to apply new knowledge by the expenditure of capital, and upon the willingness of the community to accept some present saving in consumption in order to effect a permanent improvement in the future standard of life.

It has already been pointed out that any new basic knowledge which is evolved is, broadly and relatively quickly, available to all, and it is, therefore, upon the *technological skill in application* that the progress of industry and, therefore, the economic position of the nation will mainly depend. Even in the short term, the improvement of output from existing plants depends, to a major degree, on technological handling and scientific approach.

It can thus logically be argued that industrial progress of the kind referred to depends more and more upon ' brains ' rather than on ' brawn ' for its continuance. It would, in fact, be reasonable to expect that the supply of well educated personnel, and particularly those with technological training, should more or less keep pace with the growth of production, and at a similar compound interest rate. It is appropriate, therefore, to examine now what has been the general progress in the field of education and training of the required type, and to compare this with the corresponding changes in productivity.

DIAGRAM 5. PLASTICS PRODUCTION. COMPARISON OF U.K. AND U.S.A.



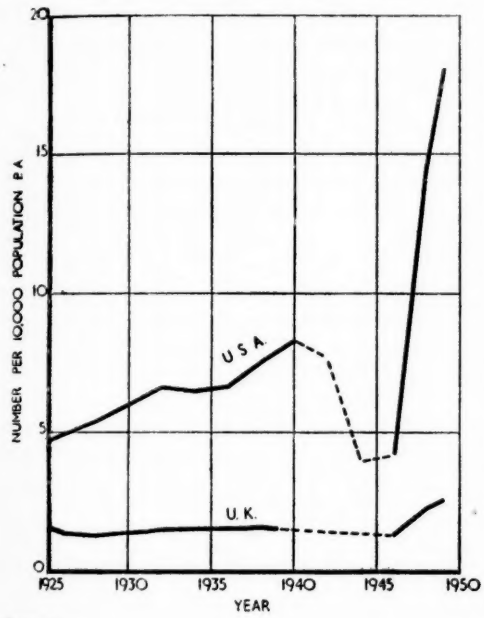
Sources :
Annual Abstract of Statistics. No. 84, 1935–46. No. 86, 1938–48.
Chemical Economics Handbook, Stanford Research Institute, U.S.A.

In a complex matter of this kind—involving, for example, an examination of the numbers of scientific and technical staff trained per annum in this country and in the United States or other industrial countries—it is clearly of doubtful value to compare numbers directly, even when corrections are made for the difference in total population. This is because standards of training, of assessment, and of background vary so widely between different countries ; even where the same terminology is used, the entities referred to may be appreciably different. On the other hand, it is both possible and fair to compare the *rates of change* which are evidenced in the same fields of activity but in different countries, provided these

trends are considered on a long term basis, cover broad aspects, and are not used to support deductions of a limited or localised nature.

The statistics of university and technical college education which are available

DIAGRAM 6. FIRST DEGREES (MEN) IN ALL FACULTIES. COMPARISON OF U.K. AND U.S.A.



Sources :

U.K. Annual Abstract of Statistics. No. 84, 1935–46. No. 86, 1938–48.

U.S.A. Statistical Abstract of the United States, 1932–48.
Earned Degrees Conferred by Higher Educational Institutions.
Earlier Years from Statistics of Higher Education (Biennial Surveys).

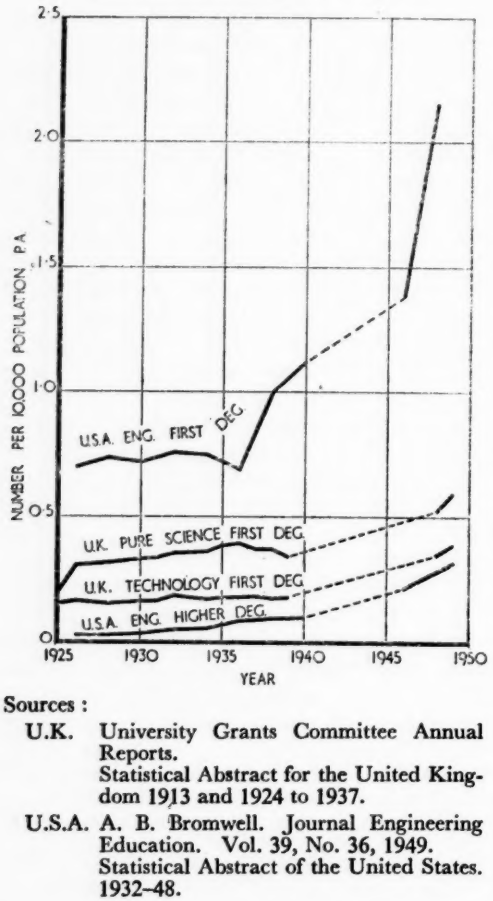
for the principal industrial countries vary greatly in their scope and basis of compilation. It would be of great benefit to have this data in a co-ordinated form, and this is a task which might well be undertaken by an international body such as UNESCO.

For the purpose of this paper a considerable search of British and American records has been made, and some data has also been obtained with reference to Switzerland and Germany. It is not necessary to quote the results in full, but Diagrams 6, 7 and 8 illustrate the trends of university education. In all countries the recent world war has resulted in a marked increase in higher education over the past five years. It is true that the output of British universities has been doubled in comparison with pre-war years, but this is by no means abnormal when compared with the expansion which has taken place in the United States (Diagram 6). When the long term trend is examined, however, it is noteworthy that the latter country was, on the average, showing a steady increase between the two world wars of approximately 3·6 per cent. per annum at compound interest as against 1·8 per cent. per annum for the United Kingdom. These rates should be compared with the overall rate of change of productivity shown in Diagram 1. Special stress is put on the rate of change rather than on the relative output per capita in order to avoid any objections which may be raised on the score of relative standards of quality, although the best institutions in America do clearly reach a very high level in many respects.

During the relatively stable inter-war period, United Kingdom degrees granted in applied science (technology) per 10,000 of the population increased only from 0·16 to 0·18 per annum, whereas in the United States, first degrees in the single technology of engineering grew from 0·7 to 1·05 on the same basis (Diagram 7). If the present position is considered, it appears to be equally disconcerting. The rapid increase in the award of higher degrees in the United States is very notable ; thus, in 1938, the number of such degrees granted in that country in engineering alone was 0·1 per annum per 10,000 of the population but by 1949 it increased to 0·3, and was then approaching the United Kingdom figure of 0·38 for first degrees in all technologies.

Before the late war, degrees in applied science in the United Kingdom represented only some 10 per cent. of the total in all faculties, but in spite of the drive to improve the application of scientific knowledge to productive ends, this percentage had only risen to approximately 12 per cent. by 1949 (Diagram 8). It is also to be noted that, although the numbers trained in pure science in this country showed a definite increase in the inter-war years, the output of the universities in

DIAGRAM 7. TYPICAL TECHNICAL DEGREES (MEN).
COMPARISON OF U.K. AND U.S.A.



Sources :

U.K. University Grants Committee Annual Reports.
Statistical Abstract for the United Kingdom 1913 and 1924 to 1937.

U.S.A. A. B. Bromwell. Journal Engineering Education. Vol. 39, No. 36, 1949.
Statistical Abstract of the United States. 1932–48.

applied science was relatively static at less than half that figure. In 1949 the ratio of degrees in applied science to those in pure science was exactly a half, i.e., it was no better than in 1925. In the United States and other industrial countries the output of university-trained technologists is, of course, greater than that of those trained in pure science. It may well be said that this country spends much effort in research for others to reap the effective benefit in application.

The above broad survey, crude as it is, leads inescapably to the conclusion that, for a given (world) level of fundamental scientific knowledge, a major influence on the long term trend of productivity is the rate at which applied scientists are trained and used in industry. To a considerable extent, the output of such men must be determined by the industrial demand. This demand is greatest where industry has a progressive outlook and is already striving for increased efficiency ; such an attitude is likely to be fostered by applied scientists as their numbers increase, so that the effect is cumulative. It is important, therefore, that industry should be encouraged to call for and use men who have had higher technological training, and that the rate of output should be steadily increased to match this growing and cumulative demand.

A serious result of the present shortage is the growing unbalance between the rewards offered in industry and in the teaching field. The numbers and quality of men offering themselves for teaching science in the schools appears actually to be going down at a time when the national need is for a strong upsurge on this side.

Although reference is made primarily to university training it should not be inferred that the argument applies only to graduates. Not only do we need to increase the output of the most highly trained people to permit them to be used for a wider range of functions, but we also need a general up-grading of the technical training of all our industrial manpower to keep pace with the increasing demand for ' designers and managers ' rather than for manual workers. In this connection, it is very satisfactory to note the high and steady rate of growth which has been achieved in the National and Higher National Certificate curricula as well as in Diploma courses. If progress in higher education had been on a similar scale, the problem under discussion would be well on the way to solution.

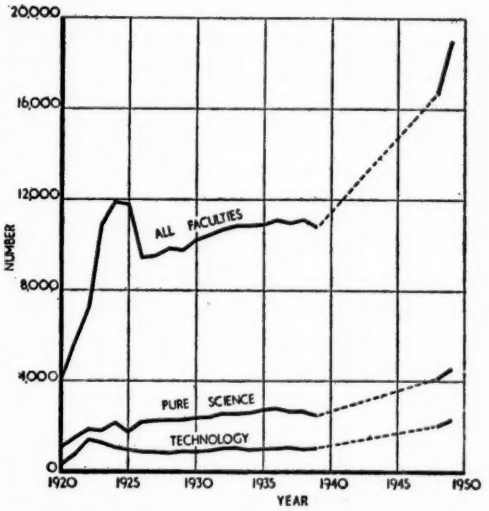
Above all, however, it is the training and ability of the leaders which is of the greatest importance to the national progress and well-being. In an industrial country such as our own, and in a technological age, there is a clear need in all walks of life for a proper proportion of men who have had an education to university standards and particularly on the scientific and technological side.

This is not intended to belittle the Humanities, but to stress the need for the application of the scientific and analytic

approach on the part of management in all its branches—industrial, economic and political. The traditional type of education in the classics or other 'arts' subjects is not, *by itself*, very appropriate to the technical and managerial requirements of the present times, but we still cling to it to a far greater extent than any other industrial nation. Conversely, those who receive higher education in the sciences tend to exclude everything outside their immediate and specialised field. To quote Mr. Patrick Johnson (*Times Education Supplement*, February 3, 1950), far too many of our scientific and technical courses still 'purvey instruction rather than education.' Many of the major seats of learning on the Continent and in North America are already tending to be ahead of us in this respect. They not only train a higher proportion of their people for the application of science, but they train them to have wider interests and place emphasis on those aspects which are of importance in the managerial function.

There are two further matters in connection with the educational and general approach which we should do well to consider. The first is the longer graduate and post-graduate training which is now normal in other countries. This is needed to cover the growing scope of every scientific subject and to allow for the wider education referred to above. (The average length of courses here is at least one year less than in comparable institutions abroad). Secondly, there is a common belief in this country that a career in applied science in industry is in some way inferior in status to that in the other professions. No doubt there are historical reasons for this attitude, but it is now completely out of accord with present-day conditions and is certainly detrimental to our needs. As a result, boys in their formative years are often steered away from, instead of towards, a desire to acquire knowledge for application to practical ends. It is still considered a higher calling to carry out pure scientific research or to study classics, or history, than to apply the accumulated knowledge of the world in productive industry, to the benefit of mankind. Again let it be stressed that this is not intended to decry the importance of the humanistic background in industry as elsewhere, but it is a plea for balance, for mutual understanding, and for a progressive approach in the whole educational field. Those who study in the classical tradition might well be given a better appreciation of science and of the

DIAGRAM 8. ALL U.K. UNIVERSITY DEGREES (MEN AND WOMEN). CONTRIBUTIONS BY PURE SCIENCE AND TECHNOLOGY.



Sources :
University Grants Committee. Annual Reports.

functions and ideals of modern industry. Equally, those trained in the sciences need a much wider grounding in the Humanities than they usually receive. If this leads—as in time it must—to a lengthening of the period of formal education, let us face the facts and take appropriate action as other nations are now doing.

It is the purpose of this paper to emphasise the need for a continuous increase in the 'weight' (numbers and quality) of our manpower resources for the application of science, rather than to consider how this might best be done. It is, however, the writer's belief that the necessary improvement should come by the natural growth and evolution of our existing scholastic and academic institutions, and also by the founding of new colleges, as and when this becomes necessary to meet the growing need.

There is much present controversy about the upgrading of selected technical

colleges. It is to be hoped that this movement will go ahead on sound lines and that a valuable addition to our strength will result, but until we have colleges with the outlook, the facilities and the status of such centres of technological training as those of Zürich, Stockholm, Charlottenburg, Delft, Massachusetts Institute of Technology, California Institute of Technology, etc., the full weight must still fall on our universities.

The schools, and particularly the public schools, have a vital part to play, not only in their actual teaching, but also in their approach to science and industry, and thus in the way they condition their pupils' minds to their ultimate careers. This is not only of importance from the national aspect, but also to the boys themselves, for men with 'arts' degrees are already finding it more difficult to obtain posts than those with scientific and technical training, and all the indications are that this trend will continue.

The universities in this country have moved far during the past 50 years, but it is unfortunate that most of the expansion should have taken place as a result of a sudden increase at the end of each world war. (See Diagram 8.) Such discontinuities place a load on the educational system for which effective preparation cannot be made ; they also lead to a sudden expansion of a particular class and age range of staff in industry which cannot be matched by a corresponding and immediate increase in the upper parts of the organisation pyramid. On both sides, difficulties and inefficiencies result.

It has been pointed out how slight was the change in this country in the output of graduates between 1925 and 1939. This was certainly not in accord with the world trend of technological advance and appears to indicate a lack of appreciation in this country of the need for that steady and continuous development which is so vital to an industrial community. Are we to depend on wars or economic upheavals to make us move in these matters ? If so, the prospect is not a happy one.

The application of scientific knowledge to industrial production depends primarily on engineering and related technologies. In support of the general case put forward in this paper, it may be appropriate to quote from the remarks made by a distinguished American, Mr. Mervin J. Kelly, Executive Vice-President of the Bell Telephone Company, at the Conference on Higher Technological Education organised by the Royal Society in March of this year. He said :

'Engineering graduates are used in an increasingly large area of the industrial operations of our society. Through the years, there has been a continuous increase in the area of use of the engineer in the activities of manufacturing, distribution and technical service . . . and the top few levels of management of manufacture are largely filled by engineering graduates. The distribution of industrial production and consumer goods is planned and directed by engineering graduates. The service industries in their management and technical operations are also manned increasingly by engineering graduates.

'This broad extension of area of use of the engineer beyond the professional operations of development and design has been one of the most important elements in the rapid increase in our industrial power. I am confident that our technological progress would have been much slower and our country's industrial strength of a considerably lower order if our technical education system had not supplied the large volume of adequately trained engineers for use in the management and technical operations of an ever increasing area of our industrial society.

'If the technically trained man, the engineer, now occupied the same area in your society as he now occupies in that of my country, it would be necessary for you to increase your engineering graduates by at least a three- to five-fold factor.'

Conclusions.

By world standards our objective should be to increase our *overall* national productivity by not less than, say, 5 per cent. per annum for many years to come. Technically, this is a modest target, but all the evidence indicates that for achievement it would require a similar rate of increase in the output of personnel trained and eager to apply scientific knowledge and scientific methods to practical ends. It would be inappropriate to discuss here all the industrial, political and psychological factors involved in achieving such a rate of change, but it may be remarked that all sides would be helped by a more scientific and objective approach.

Our university faculties have now some 27,000 full time students in pure science and technology, so that a 5 per cent. rate of increase at compound interest would mean an addition of nearly 1,500 per annum now, and a still bigger increment as the years go by. The magnitude of such a task is serious, but our future national prosperity will largely depend on how far and how fast we as a nation face up to it and take appropriate action. Although we have recently doubled our output after 25 static years, this does not make up our leeway, nor does it remove the need for continuing expansion in accord with the laws of natural growth.

THE MEANINGS OF TIME AND SPACE IN PHILOSOPHIES OF SCIENCE[1]

by

DR. MARTIN JOHNSON

1. INTRODUCTION : TIME AS THE BASIC QUANTITY IN PHYSICS

IT is usually supposed that any ultimate problem of science must introduce some mystery of time and space, and we certainly do uncover many phrases difficult to see through when we use either of these words. I would like to begin by asking whether we give the same meaning to Time in the following five instances : when observations of nebulæ are alleged to imply that the universe 'began' two thousand million years ago, when an electron is said to occupy an atomic energy level for a hundred millionth of a second, when Eddington said that thermodynamics can decide the irreversible direction of Time, when a philosopher claims to prove that Time is 'unreal,' when a poet or a moralist says that human endeavour is to defeat Time. It seems possible that different kinds of scientist, in mathematical physics, in astronomy, and in psychology, utilise quite different conceptions when they talk about Time, concepts not uniquely derived from our universal experience that events occur in a temporal sequence ; and when, instead of being scientists and trying to argue logically, we exploit instead our imaginative gifts, it seems likely that in poetry and in religion the whole concept of Time still further diverges from any simple use of Duration, Succession, and Simultaneity. Again, until recently it was common among philosophers to prove that Time must be unreal, while today's Logical Positivists would say the proof and even the problem is meaningless.

So I propose forthwith to try to separate some of these notions of Time. But I am very mindful that whatever definitions and distinctions might evolve from the most learned analysis, the inescapable practical business of life confronting us all is to snatch from the brief transience of experience the chance of building in personality something more lasting than what we temporarily love or fear. In that sense the goal of all human endeavour is to 'defeat Time'—implying a meaning of Time which scientific argument is bound to ignore in silence ; only superficial thinking will interpret that silence as disapproval, since there is no possibility of formulating any scientific statement for or against.

Much of what I have to say belongs to the theory of Relativity, or rather the very differing theories of Relativity which began with Einstein's pioneer work and range through the less-known researches of De Sitter of Leyden, Milne of Oxford, Bondi and Gold of Cambridge, and especially the new implication in 'continuous creation of matter' recently popularised in Hoyle's

[1] Paper read to the Mathematics Sub-Section, at Birmingham, on September 5, 1950.

brilliant broadcasts which have attracted a wide public to cosmology. But I am not attempting to provide yet another successor to hundreds of expositions of Relativity—from Eddington to Hoyle there are plenty of able popular books arguing its basis with clarity suited to everyone's taste ; I shall state in a few sentences requiring no background the several points needed, and shall attempt the novelty of extracting the physical significance about Time, shorn of the detail which has often clouded the issue.

It would seem inevitable that whatever material, spatial, electrical, etc., quantities may become transformed away as physics reduces the number of its fundamental concepts, Time must remain the quantity always explicit or implicit in its equations and laws. Crudely stated, we may say physical science is interested in the changing or the flux of the world, not in any static picture, and is in fact a study of a sequence of events whose basic pattern is a time-order. It is instructive to notice how modern science began with this recognition : ancient and medieval world-pictures were sufficient if they were fixed geometrical representations, but Newtonian days replaced these by gravitational schemes. All such mechanics, through introducing the possibilities of Cause and Effect, enforced upon science the study of sequences, or events spread out along a time-order. Today, thanks to quantum mechanics and to relativity, we are not so sure as were our grandfathers that Cause and Effect has any simple mechanical meaning, and in Heisenberg's Uncertainty Principle we become aware of quantitative limits to causal inference ; but however shrewdly we widen our definitions and replace causal laws by functional dependences to satisfy this or that extension of our logic, one of the variables in the function is labelled ' t ' for Time. Maxwell's equations of electromagnetism, like Newton's mechanics, are capable of expressing laws of Nature as the variation of some quantity with time, and even with full regard to Dirac's warning against demanding pictorial associations for the terms in our differential equation, atomic wave-mechanics is still in its usable form a time-fluctuation of electrical quantities. Thermodynamic arguments about Time were commoner a generation ago than now, and Eddington's famous ' arrow ' deciding why Time is irreversible is no longer quoted ; this is because many thinkers are unhappy as to what can be meant by local enclosures in the Second Law of heat-exchange. So the ' heat-death ' predicted as the future of the universe by an older generation may be no longer a nightmare ; but the status of physical science as the correlation of observation and experiment into patterns of time-order has not been modified by any development of recent science or philosophy of science. In fact Time is always ' real ' enough for physics, more so than any other quantity, whatever twist to the meaning of ' reality ' may ever be given by various philosophies.

On the other hand, drastic changes in how we utilise the notion of Time are an important but subtle feature of today's science, as follows.

2. Relativity of Time-measure and Space-measure

Einstein's earliest Relativity theory, before the first War, made two great alterations in what could be thought concerning Time ; one alteration has lasted with honour, but the other has been misleading. The first was to interpret the previously-known Lorentz transformation as a ' relativity ' or lack of Absolute character, in space-measure and time-measure. Experiments had shown that the adjustment of Newtonian quantities, expressed by Lorentz as a correction to an observer's spatial and temporal estimates according to his own velocity of travel, implied that different observers seem to discover the intervals between events as time-like or as space-like according to the moving situation from which each observes. Einstein's great advance was to replace the previous clumsy interpretations of this, a supposed shortening of measuring rods and slowing of clocks, etc., by the drastic admission that there is no such thing as absolute measure, spatial or temporal ; the only reality remains the individual partitioning, such that for one observer the separation between two events actually is space-like and for another observer it is time-like. Absolute simultaneity between events

watched by different observers in relative motion to each other becomes meaningless, except under specifically restricted conditions. Hence in relativity the relations ' before ' and ' after ' do not express unique truthfulness or falsity as had been assumed in all previous scientific outlook.

Minkowski's famous expression of these permanent discoveries of Einstein turned out to be less reliable ; his diagram separates futures and pasts, and shows where succession and simultaneity are interchanged by different observers of the same events : it is thus always a valuable aid to visualising the Lorentz transformation. But his dictum that 'henceforth space and time are merged into a single entity ' led many philosophers to suppose that the use of these terms as adjustable co-ordinates in a single equation implied some vague but compelling grounds for both to play equivalent parts in our judgment of Nature. This is quite wrong : even at the crude practical level we must recognise that we can manipulate spatial separation in a way impossible with Time, which cannot be juggled with. It took the less publicised labours of De Sitter in Holland and Milne in England, and a few others such as Robertson and Tolman across the Atlantic, to give a different status to Time, even if we do not all agree as to whether the difference in status has been correctly estimated by any of these.

3. Time in the Interpretation of the Red Shifts of Nebular Spectra

The problems about Time which face us today arise not so much from relativity at the Einstein stage, but from the puzzling displacement of lines towards the red end of the spectrum of the most distant nebulæ. These nebulæ are now known each to be swarms of millions of stars, comparable in size with the whole Milky Way which itself contains all the stars known individually to us : they are far more distant than the Milky Way and are properly external galaxies or external universes—if we allow such abuse of that word. Since a displacement of spectral lines towards the redder end of the spectrum is, in the laboratory, usually a Doppler effect or measure of the speed at which the source of light is receding from us, it has been customary to suppose that these galaxies are all rushing away from us at speeds which on this interpretation are very large indeed. We have no independent measure of the actual distances of these swarms or galaxies, but a few of the nearest can be assessed from the pulsating stars they contain, whose properties and therefore distance for any given brightness can be found. The galaxies appear on this method or rating to be at least three-quarter million Light-Years away. That is, the nearest are so distant that light travelling at 186,000 miles per second takes so many hundreds of thousands of years to reach us after setting out. On the very reasonable assumption that smaller photographic images of similar shape and character denote somewhat similar objects even more distant, a correlation between distance and this apparent speed of recession has been found, and the further off they are the faster they recede from us, some at 100 million Light-Years receding at 12,000 miles per second. That is faster than anything we meet except for certain electron projectiles, in radioactivity and the extreme accelerating fields in the atomic laboratory.

It is the rule of the game in astronomical physics, that one must interpret large-scale phenomena by the laws already found to hold in the laboratory, before guessing at new kinds of mechanism. Without this sensible rule we would be lost in a chaos of random fantasies, over which there could be no check or verification. So the first thing to do is undoubtedly to begin by investigating the consequences of supposing that these mysterious and enormous red shifts are just Doppler effects, i.e. the well-known laboratory phenomenon of a receding velocity. Only when we reach a dead-end by such assumption may we introduce some new explanation as a hypothesis without laboratory support. So the scientific world has generally accepted this interpretation of the nebulæ as violently receding, and reservations of opinion have been associated with De Sitter and Milne and few others ; not even they deny the possibility that the nebulæ are receding, they do however admit that alternative interpretations are also possible, since we cannot be sure that Time measure means the same at those distances

or so far back in the history of the universe, millions of years ago, when the light which we today see was actually emitted. But the conventional interpretation, that the red shift means recession, is not a dead-end : on the contrary, whether right or wrong, it raises the majority of the current puzzles about the structure and destiny of the universe. Let us look at some of these puzzles which they set concerning Time.

We spoke of Relativity as deciding the status of the co-ordinates in which physical properties are expressed, measures of space and time ; consider the possibilities that instead of these nebulæ rushing away from us at such enormous speeds, either the space measure or the time measure is itself different on the universal scale from that defined in terms of the measuring rods and clocks of the laboratory.

The first, the theory genuinely implying an ' expansion of the universe,' was popularised by Eddington through his brilliant analogy of spots embedded in the rubber of a balloon and then separating as the balloon is gradually inflated. If the balloon fabric is a two-dimensional representation of the space which we actually experience as three-dimensional, the spots recede from each other because their rubber framework is enlarging, although not themselves endowed with any motion as measured in the spatial co-ordinates of any one instant. The analogy does convey some pictorial notion of how space itself might be enlarging at a rate which makes the nebulæ seem to recede from us. This theory came from Lemaitre's and Friedmann's mathematical investigation of the stability of a ' closed ' space, a conception again illuminated by Eddington's two-dimensional analogy of the orange-skin, which is ' finite yet unbounded.' It must be remembered that the whole conception of closed space, which means that at least one dimension exhibits ' curvature,' comes not from empirical definition, but from a property assigned to co-efficients in the tensor equations which are one way of representing accelerated motions of observers. It is a severe strain on this particular and beautiful method of reducing physics to Riemann's geometry, to treat such ' curvature ' of any dimension as if unique, and as if, further, such curvature were a physical property subject to the physical liability to *alter itself in time* which is a liability with no geometrical status at all. Its entry into science is a prime example of selection of a concept by æsthetic appeal.

The other alternative, that time-measure on such large scale is not what we meet in the laboratory, was first mooted by De Sitter. His model universe, unlike Einstein's, had curvature (or the appropriate variability in co-efficients of the tensor equation) in the time dimension as well as the space dimensions ; hence at large distances, such as those locating the nebulæ, time-measure is retarded, giving the red shifts of the spectra which would otherwise be attributed to movement of recession. At a certain distance, the retardation becomes so extreme as to make time ' cease to flow ' for the observer here, a quaint mathematical version of traditional eternity. There are grave difficulties in accepting De Sitter's scheme, which in his lifetime seemed quantitatively insufficient to account for all the facts : in any case it was an approximation based on an empty universe, and it was forgotten under Eddington's winning popularisation of ' expanding space.' Another account of the same phenomenon, also somewhat undeservedly neglected, was Milne's very common-sense demonstration that if you let loose a swarm of particles, whether gas molecules or universes, unrestrictedly, the faster among them will eventually find themselves the furthest away from the starting point : which is the observed phenomenon without requiring any change in space-measure or time-measure to explain it.

Milne's other contribution is not so much the urging of a new explanation but the demonstration that no one explanation is uniquely provable against its alternative. He showed that there are at least two ways of constructing time-scales, and that these would diverge appreciably during the long life of the universe, though not detectably separable on the small dimensions of a laboratory or even solar system. He and his associates have done much research towards identifying the mechanics of experience with one or the other time-scale, but many physicists remain unconvinced and others accuse him of spinning a web

out of pure logic instead of out of experience—an accusation which Eddington in his time also stood up to. What is important, apart from any future decision as to the correctness of Milne's deductions, is that he shows that more than one scheme can comprehend the nebular red shifts: (a) a universe in which all objects recede indefinitely from the observer—this is the real Doppler velocity, a genuine motion of the nebulæ instead of Eddington's expansion of the spatial framework. (b) If the alternative time-scale is chosen, and there seems no incontestable ground proving one or the other, the time-scale itself is altering; long ago, when the light set out from those distant galaxies the atomic frequency in spectra was smaller as judged by today's scale, so that today it is absorbed in our apparatus as a spectral line displaced towards the red. We are presented with the two equivalent alternative pictures, either an expanding cloud of nebulæ or a stationary universe with the clock of Nature read as slower for the more distant, not as De Sitter supposed because of a curvature in the time dimension, but because light was emitted from those distant galaxies at an epoch much earlier in the history of the universe and reaches us only today millions of years after.

This healthy reminder that if any one explanation can be found to fit the mystery, another may be equally true if we adjust our way of measuring, has the same defect of Eddington's expanding space; it raises a very difficult conception of what was the state of things 'at the beginning,' i.e. when 'time began,' which is as hard to grasp as the notion of when space itself was packed into a small starting point. This difficulty is, I think, the most compelling reason why we turn in relief to see whether there is any comfort to be had from the 'continuous creation of matter' advocated by Hoyle in his broadcasts, and devised by himself and also independently by Bondi and Gold and by Jordan, and in fact traceable back to a paper by Dirac as early as 1937.

4. Hypotheses of Continuous Creation

Before the recent physical sciences were forced to concern themselves with conditions supposed to characterise the 'beginning' of their world, the valuable generalisations 'conservation of mass' and 'conservation of energy' had never been doubted. That is to say, we had found it a consistent guiding principle to believe that materials and energies change their form but not their total amount. The furthest encroachment had been the uniting of the two conservations: there had been the speculations of Jeans, and quantitative work by Sterne and others, on the transformation of matter into radiant energy, and vice versa. Such speculation, even its thermodynamic treatment, had been not unreasonable to expect ever since Einstein's very important discovery that inertia and energy are equivalent; the practical utilisation of gained energy from lost atomic mass provided the war-time atomic bomb, and its peaceful exploitation is today the preoccupation of every government to employ scientists. But when the red shifts demand that we face at last the question of an origin or starting point in either a contracted space or a zero of time (whichever we adopt of the several possibilities I have described), it becomes anomalous to picture a full complement of energy or mass when we are trying to envisage a limit or a zero of space or time.

In fact we reach a choice, perhaps an æsthetic or imaginative choice, between three inconceivables, the start of space or of time or of matter, and the recent cosmologists called the 'New' have chosen the latter.

If this is done, some notion that matter was created becomes inescapable. The difficulty of envisaging an instantaneous spring to a full universe makes it inevitable that some bold minds should take the initiative and propose that it will be less difficult to suppose matter is being continuously created always. Whether we regard this as *the* new cosmology, or only one of indistinguishable alternatives, may perhaps be decided by comparing the grounds on which the new hypothesis has served its several authors.

Hoyle reaches it by considering the requirements for satisfying the 'cosmological principle' of relativity, i.e. the interchangeable character of observers, without introducing arbitrary constants

such as had troubled Einstein and De Sitter about curvature of space, and allowing for an expansion among the nebulæ and certain limits to the density out of which nebulæ have themselves condensed. He shows, on his theory of how nebulæ do gather material, that this density is rather sensitively determined.

Jordan, an earlier and less detailed advocate of continuous creation, adopted the puzzling numerical relationships between physical constants, gravitation, electronic mass and charge, etc., which had so intrigued Eddington ; he found that among them the ratio between ' mass of universe ' and ' mass of particle,' therefore total number of particles in Nature, depends on a quantity derivable from the red shifts as an ' age of the world.' Jordan attempts to retain with this brand of continuous creation some respect for the Principle of conservation of energy, since he derives his ever-increasing mass from ever-diminishing potential energy of gravitation, and envisages a maintained balance. Hoyle achieves this balance, correspondingly, when he supposes distant matter to pass out of physical reach as fast as it is replenished by creation.

Bondi and Gold reach their continuous creation by the more philosophic path of placing at the head of all scientific knowledge a widened postulate of the kind called Cosmological Principle. We have referred to this already, as a requirement that observers should be capable of agreement : in some form or other it has guided everyone since Lorentz and Einstein first sought the conditions under which observations can be transformed from one situation to another. Milne extended its use in cosmology, and now Bondi and Gold use it as the touchstone deciding where laboratory physics and physics of the widest world of Nature can be made equivalent. They go so far as to say ' one must if necessary reject theoretical extrapolations from experimental results if they conflict with this Principle, even if the theories concerned are generally accepted.' A primary deduction from this Principle they find to be a continuous creation of matter, maintaining a universe steady in its properties, including average density, although expanding.

Comparing all these investigations, continuous creation arises as a hypothesis whenever we are forced to ask what happened at a time extrapolated backwards from the present to an origin dated by the redshifts ; it becomes a way out of impasse, when the impasse is either the difficulty of how nebulæ condensed, or of what is meant by density in space before expansion began, or of what is meant by a beginning on a time-scale.

The comparison between these several reasons for postulating continuous creation suggests that we are capable of manipulating spatial or temporal or inertial quantities in our equations, but not all three together ; so that we are forced to indulge in arbitrary selection at some stage, if we are to satisfy a Cosmological Principle. In proceeding to infer any advance in the original problem of whether physicists can have some characteristic attitude to Time, there are two important effects in philosophy from our analysis of the logic of recent relativity, which can now be very briefly mentioned.

5. Scientific Restriction upon Metaphysical Views of Time

A considerable proportion of the effort of philosophers in the nineteenth and early twentieth centuries, and of great individual thinkers before, notably Spinoza in early modern times and Platonists in the ancient and medieval worlds, has been devoted to proving that Time is unreal. Definitions of ' reality ' tend to fog any such decision, but man's philosophic outlook on destiny has certainly been inseparable from some implicit ' coming to terms with ' the problem of Time. But here the study of relativity makes one conclusion inevitable—relativity is not a metaphysics, but it does eliminate some portions of metaphysics. If ' real ' means that a certain characteristic is inescapable, undeniable, and incapable of being transformed away by any concept more fundamental, then Time, or the existence of a temporal order of events, is the most real of all physical facts. We have therefore reinforced the widespread use of Time in general physics, described earlier, by recognising that even if we fail to decide between the various relativity theories

they must at least impose either nebular distances which are time-dependent, or a space-frame which is time-dependent, or a scheme of time-reckoning which itself alters with age. We even found the newest cosmologies invoking continuous creation just because of the difficulty of grasping spatial and temporal characteristics far removed in time from the present, difficulties escaped by no one of the relativity theories.

Hence, unless metaphysics decides that the world-outlook of the physical sciences is a negligible contributor to general philosophy, it cannot treat Time as unreal. A century ago such neglect of physics would have been possible, but scarcely today.

If we turn instead to regard the mental sciences, the psychology of memory, which contains in some ways the most fundamental grounds for decision as to our ultimate assessment of the human mind, is itself entirely a study in temporal sequences. A metaphysics taking reasonable account of either psychological or physical sciences is therefore bound, from either approach, to accept temporal relationships as real : as we may crudely say, Time is the most fundamental and inescapable feature in experience. When humanity aspires to freedom from the bondage of Time, it must be by moral conquest not metaphysical evasion.

6. The Status of Unprovable Theorems Concerning Time

This abandonment of the earlier philosophers' major task is also part of the programme of the very flourishing contemporary school of Logical Positivists ; they go further and condemn most of the traditional metaphysical problems as meaningless, where such problems are incapable of being solved either by logical analysis or by direct sense-experience. It has been a very healthy change for abstract thinkers to recognise that the too-comprehensive metaphysical systems, which used to explain all features of the universe, are none of them watertight, or ever likely to be ; where Logical Positivists have often gone beyond natural mandate is to suppose that problems become trivial if they are thus insoluble as far as proof is concerned. ' Meaningless ' is a term which must be carefully used, since, for example, æsthetic and ethical judgments are also unprovable by direct reference to sense-experience or to analytic judgment, but we are all aware that they contain significance which is going to make or end civilised life. The existence of any world at all external to the individual and his subjective sensations is, as Bertrand Russell long ago contended, a mental construct unprovable in metaphysics : we ' believe in ' a lot which we cannot prove, and it is profitable to recognise our impotence so long as it does not lead to the superficiality of despising what we cannot see through. The wiser Logical Positivists realise that much of the stock-in-trade of the older philosophies has ' imaginative significance,' and our attitude to Time has at some stage to take up its responsibilities under that category. Let us see therefore what part is played within cosmological physics itself by imaginative decisions—it may be found that these outlying borderlands of the physical sciences have more in common with the poetic or artistic attitude to experience than the solely logical.

7. The Cosmological Principle and the Choice Among Attitudes to Time

The continuous creation of matter may be a fact, but it is not at present susceptible of proof ; and it is possible that it is essentially not provable, since no direct discriminatory evidence exists, and we have shown that logically its mandate is to fill a gap. In fact the gap is just where limiting values along a time sequence raise the question as to any initial amount of inertia with which we are to suppose the universe endowed ' in the beginning.' The properties of time-order and of mass may perhaps become the twin uncovertable characteristics of the world known to physics, so that impotence to formulate logical statements about either one is bound to vitiate every advance in understanding the other—almost as Heisenberg's Uncertainty Principle condemns us to know less about momentum the more we know about location of an electron, or as Bohr's Complementarity Principle condemns us to

know less about what we locate in co-ordinates the closer we locate it.

This makes the choice among some recent relativity theories, e.g. De Sitter's or Bondi's, an æsthetic rather than a rational choice, and we recollect that Milne's relativity itself contains two alternatives in which there is arbitrary choice between a stationary universe on a moving time-scale and an expanding one on a fixed time-scale.

It would be an investigation profitable to a psychologist, interested for once in the scientist's mind and temperament as his specimen for study, to ask whether the various Cosmological Principles, especially that to which Bondi gives so vivid importance, are really the quantitative ways of expressing an optimistic faith that ' Nature will be intelligible.' I have in some books on philosophy of science associated this optimism with the need for science to be expressed in communicable form if it is to be genuine knowledge, and have pointed out the likeness to principles governing artistic or poetic creativeness. Cosmology would be poor sport if there were not always the aim of discovering equations capable of representing the universe itself, not merely the way in which one particular observer is condemned to envisage it : as Dirac claims, physics advances by discovering more universal transformations. Unless one believed that Nature has an orderliness of its own, we would not long pursue scientific enquiry ; and it is appeal to such orderliness which guides the relativist, a guidance which Bondi and Gold more than others except De Sitter and Milne have respected. The choice as to whether Time or inertia are variable or constant measures, and what their zero limits can mean, becomes therefore an æsthetic or imaginative choice demanded by that optimistic belief in intelligibility, outside the pale of the logical positivist but as vital to our outlook as are some other non-logical decisions.

8. Science, Aesthetics, and Morality, in Decisions Concerning Time

Having contended that science is inevitably tied to dealing with Time, but is ultimately driven to æsthetic or imaginative rather than logical grounds for selecting how to formulate its time-relationships, we return to the beginning of our enquiry with this hint that the physicist and the poet or moralist may in some ways be not so far apart as at first supposed. An imaginative decision is one demanding provisional settlement on grounds other than sense-experience or analytical proof, and the physicist attempts such a settlement in all his uses of the Cosmological Principle ; the poet and artist make similar decision when they accept the world as well worth selection of memorable aspects expressible through supreme skill in pattern of word, sound, or visual art. Without such imaginative acceptance of an unprovable value, the never-ending struggle, to express the glory and the pity and the terror of life would fail, and art and poetry die—and science would never go beyond technology. The moralist makes similar unprovable venture into the dark of uncertainty when he decides that a given mode of behaviour is worth while even at cost of loss or death. In the course of everyman's struggle to ' defeat time ' by transforming transient experience into more lasting personality, we have our religious moments of faith that we are making something everlasting ; and in those instants of vision we take a step into adventure unsupported by logic, as does the poet willing to believe life worthy of the agony of expressing it. I have tried in this essay to show that the physicist is also driven to an arbitrary selection on æsthetic grounds of how to treat his fundamental quantity of temporal order. None of these trespassers beyond logical proof need be ashamed, so long as the trespass is honestly committed and no more claimed for it than is just.

CHROMATOGRAPHY

At the Birmingham Meeting of the Association the Chemistry Section arranged a session on chromatography at which three papers, printed below, were given. The introductory paper by Dr. Trevor Williams reviewed the development of the method and dealt briefly with its more important uses. The papers by Dr. Dent and Dr. Pollard were concerned with two applications of the method : to medicine and to inorganic analysis. In addition to the papers there was a demonstration of chromatography set up in the Chemistry Department of Birmingham University and two films on chromatographic techniques, lent by Dr. E. Lederer of the Institut de Biologie Physico-Chimique, Paris, were shown.

Some Recent Developments in Chromatography

by

Dr. Trevor I. Williams

This is an introduction to the more specialised papers from Dr. Pollard and Dr. Dent which follow. It is intended as a general account of chromatography—how the method arose and the directions in which the most important of recent developments have occurred. To achieve the first of these aims there is probably no better way than to describe briefly one of Tswett's own original experiments.

In his botanical work Tswett was interested in the pigments contained in green leaves. These pigments can be extracted into petroleum ether and if such a solution is shaken with powdered calcium carbonate many of them are adsorbed on the carbonate. Tswett modified this procedure by passing the solution over a column of finely powdered calcium carbonate contained in a vertical glass tube. He observed that, as one would expect, the pigments were adsorbed on the calcium carbonate near the top of the column. As more solution percolated through the column the region of pigmentation at the top became broader and it was observed that the colouring was not uniform. The top of the column was yellowish, while lower down it was more green. This separation became far more marked when, after all the solution had filtered through, the column was washed with pure petroleum ether. Some yellow pigment (carotene) passed right through the column, while on the column itself differently coloured bands were formed which moved slowly downwards as washing of the column with petrol ether continued. Clearly, the different pigments were being separated by adsorption at different levels on the column. By prolonged washing the variously coloured bands became completely separated from each other by colourless regions. Thus in a single operation Tswett was able both to demonstrate that chlorophyll and leaf-yellow were not homogeneous pigments and to separate components of the mixture.

Although these fundamental experiments were carried out more than 40 years ago, the development of chromatography as one of the most versatile of all methods of chemical analysis has occurred to a great extent during the past 15 years and especially during and since the last war. Among the many important classes of substance which may be separated chromatographically from the mixtures in which they are commonly found may be mentioned antibiotics, carotenoids, vitamins, amino-acids, peptides, simple and complex inorganic cations and anions, dyes, and polycylic hydrocarbons.

So much original work in chromatography has been published during the last few years that it is possible here to discuss only the developments which seem to be the most important and fruitful. Indeed, the literature is growing so rapidly that it is becoming difficult to follow even the main trends of development in the several forms chromatography now takes.

Partition Chromatography

One of the most interesting and important of recent advances in chromatography, and one which holds great promise for the future, is the very ingenious method of partition chromatography developed, primarily for the analysis of amino-acids, by A. J. P. Martin, R. L. M. Synge, and their co-workers. In this method the basis of the separation is differential partition between an organic solvent and water, the water being carried by an inert substance such as silica or paper.

The silica gel, shredded paper, potato starch, or other water-carrier is packed into a vertical tube in the usual way and percolated with the solution to be analysed. For practical purposes this column can be regarded as a column of extremely tiny water droplets, which are prevented from coalescing by the silica. Various indicators can be incorporated with the silica gel to indicate the position of the different bands. There has, however, been one extraordinarily fruitful development in which quite a different technique is used. This is the now well-known method of chromatography on paper.

In the simplest form of paper chromatography strips of filter paper are used to carry the aqueous phase and chromatograms are formed on these. The strips of paper behave as one-dimensional partition columns. A drop of the solution to be analysed is placed near the top of a strip of filter paper, which is then hung from a trough containing the mobile solvent, saturated with water, in an atmosphere saturated with water and solvent. The mobile solvent, such as benzyl alcohol, siphons over and down the strip and after anything between 4 and 48 hours the strip is dried, and then sprayed with a reagent, such as ninhydrin if amino-acids are being used, which reveals the position of the various components of the chromatogram. By this method it is possible to detect 0·2 μg. of valine or alanine, or 1·0 μg. of proline or asparagine.

Martin and his co-workers extended their method of partition chromatography on a strip of paper to partition upon a rectangular piece of paper, a most elegant and ingenious variation which permits the qualitative—and even the semi-quantitative—analysis of all the amino-acids in a protein sample weighing only a few milligrams. In forming these two-dimensional chromatograms a drop of protein hydrolysate is placed near the corner of the sheet of paper. This is hung from one side and the chromatogram is developed with a solvent such as collidine. This results in the formation of a linear chromatogram parallel to, and very near, one edge of the sheet of paper. The paper is then dried, turned through 90° relative to its former position, and the chromatogram is further developed with a different solvent, such as phenol. Finally the paper is again dried, sprayed with ninhydrin, and heated to reveal the position of the various amino-acids.

The reaction with ninhydrin can be made the basis of a quantitative colorimetric assay. The amino-acids can alternatively be located by examining the dried chromatogram in ultra-violet light, when amino-acids and peptides stand out as pale violet patches. Dent and others have described the use of radioactive isotopes as a means of locating the various components of a partition chromatogram.

Partition chromatography has been adapted for quantitative work. Woiwod, for example, located the position of amino-acids by means of a trial chromatogram, then repeated his experiment and cut out the piece of paper carrying the amino-acid to be estimated. This piece of paper was extracted with water and the acid was estimated with copper phosphate. He reported recovery of glycine and valine in excess of 95 per cent. Dent has carried out a series of analyses of urine from patients suffering from amino-aciduria and estimated the quantities of the various amino-acids by comparison of the chromatograms with those obtained by use of standard solutions of amino-acids. Besides amino-acids the chromatograms revealed several normal constituents of urine such as uric and hippuric acids, glucose, creatinine, and urea. The sensitivity of the method is shown by the fact that the analyses were conducted by placing no more than 3 μl. of urine on the corner of a piece of paper 5 inches square. The great sensitivity of paper chromatography makes it an excellent method for the investigation of metabolic changes in small pieces of tissue.

The separation of sugars by partition chromatography was first described by Partridge in 1946. Hirst and other workers have developed the method and it is reported that quantities of various sugars as low as 40 mgm. can be determined with an accuracy of $\pm$ 5 per cent. Non-volatile organic acids, too, have recently been separated on paper, using as the mobile phase butanol saturated with aqueous acetic acid.

Inorganic Chromatography

Until they became essential for the wartime atomic energy projects researches in inorganic chromatography were much neglected. Schwab and Jockers and their collaborators carried out a close investigation of the adsorption of ions on alumina. In cases where the simple ions do not differ sufficiently in adsorptive affinity for an effective separation, satisfactory results may often be obtained by percolating through the column solutions containing complex ions, for example, ammoniated or tartrated ions. In recent work, which will be referred to later, chromatography has served both to detect and to remove impurities present in such small quantities as to escape detection even by means of the spectroscope. Flood and his collaborators also have carried out over a period of several years a great deal of inorganic chromatographic analysis, using strips of paper impregnated with alumina.

Although alumina was the adsorbent used in most of the early work on inorganic substances other adsorbents have also been investigated. Erlenmeyer and Dahn, for example, used 8-hydroxyquinoline as an adsorbent. Urey and Taylor attempted, but with only slight success, the separation of the isotopes of lithium, potassium, and nitrogen by passing the chlorides of lithium, potassium, and ammonia through extremely long zeolite columns. In some cases the columns were 100 ft. in length.

Papers which must entirely change our views about the possibilities of inorganic chromatography appeared in the November 1947 issue of the *Journal of the American Chemical Society*. They covered several years intensive wartime research but had accumulated until the lifting of secrecy restrictions made their simultaneous publication possible. For the purposes of the Plutonium Project it was necessary to isolate the major fission species produced in pure form and in quantities sufficient for detailed physical, chemical, and biological investigations. This series of papers shows that a new kind of chromatographic analysis, using ion-exchangers in place of adsorbents or partition materials proved extremely satisfactory for this purpose. In particular it enabled many of the metals of the rare earth series to be separated in a state of such purity and in such quantities as would have been deemed impossible only a few years ago.

Before explaining the principle of partition chromatography something should perhaps be said of the materials involved. When formaldehyde condenses with a phenol in the presence of a catalyst a reaction takes place in which the phenol molecules become linked by methylene bridges in the *ortho* or *para* positions. Cross-links are also formed, giving rise to a three-dimensional polymer. The ionizable hydrogen atoms of resins of this kind can be replaced by cations, as in natural and synthetic inorganic zeolites, but with the added advantage that the exchange can occur under acid conditions in which zeolites are unstable. Furthermore, by using amines in place of phenols, resins can be made with which the effect of anion exchange can be made to occur. Ion-exchange resins have been developed, containing various acidic groups such as phenolic, carboxylic, and sulphonic, or basic groups such as $-NH_2$ and $>NH$. A wide range of these resins is now available commercially, and are widely used in industry for water-softening and other purposes. By packing these materials into columns chromatograms can be formed by differential exchange between ions in the column and in solution in a manner exactly analogous to those which result from differential adsorption or partition. Of the available cation-exchangers, Dowex-50 is the most important from the experimental point of view because its action groups are all sulphonic acid groups. It is, therefore, possible to get an unequivocal picture of the changes occurring.

Applying their results to the practical separation of the yttrium group of rare earths Boyd and his colleagues were able

to report separation of all the rare earths and the isolation in milligram quantities of lutecium, ytterbium, thulium, erbium, holmium, and yttrium. The selectivity of the method may be judged from the fact that a sample of erbium trioxide, in which spectroscopic examination had failed to show any trace of impurity, was found chromatographically to contain 10 p.p.m. of thulium. In this work the exchange resin used was Dowex-50, which for rare earth separations is reported to be much superior to those of the Amberlite type, although it has the disadvantage that equilibrium is attained rather slowly, so that the solutions must not be passed through the column very rapidly. The time required for the operation can, however, be somewhat reduced if hot solutions are used, though not so much as was originally anticipated. The eluant used was, as is usual, in this work, a solution containing an ion, such as citrate ion, capable of forming a complex with the ion bound by the exchange resin. Adjustment of the *p*H is important for the optimum results.

E. R. Tompkins and his colleagues applied the method to the separation of fission-produced radio-isotopes and individual rare earths. Using Dowex-50 they separated praseodymium from cerium and cerium from lanthanum. A ternary mixture of salts of neodymium, praseodymium, and cerium was resolved into its components at a purity exceeding 99·9 per cent.

The chromatographic separation of the rare earths was also effected by F. H. Spedding and his colleagues. The progress of analysis was followed by means of radio-active tracers. Using a series of 24 columns of Amberlite IR-100, each 10 cm. in diameter, and 3 metres long, they obtained large quantities of compounds of neodymium, praseodymium, samarium, and other rare earths. A typical yield of neodymium oxide, for example, was 800 gm. of 99·9 per cent. purity.

More recently research workers in London and in Bristol have shown that inorganic ions can be separated on strips of paper in much the same way as has already been described for amino-acids and other substances. It is not, however, clear what mechanism brings about the separation — adsorption, partition, exchange or perhaps even selective extraction. In a later paper Dr. Pollard describes an elegant method of inorganic analysis on paper developed by him and his colleagues at Bristol.

Industrial Chromatography

Finally, something may be said of the industrial possibilities of chromatography, which in the writer's personal opinion are very considerable. The use of chromatography as an analytical method in industrial laboratories calls for no special mention, inasmuch as the principles and methods are just the same as those already described.

Whereas chromatography is not widely used as an industrial method of analysis primarily because full advantage is not being taken of existing knowledge and technique, it is not yet used to any extent as a preparative method primarily because the many problems of working on a large scale have not been very closely investigated.

The transition from working on a laboratory scale to working on a scale large enough to be of preparative importance in industry manifestly presents considerable difficulties, though there is no reason to believe that these are either insurmountable or would not amply repay the trouble and expense of overcoming them. For those who are familiar with the extraordinarily wide applications chromatography has already found it is indeed surprising that industry generally has hitherto taken so little interest in the method. Large columns of adsorbents have for some years past been used to a considerable extent in industry, as the extensive patent literature proves, but not as a rule for chromatographic work. Their main purpose has been to remove strongly adsorbed impurities from solution, a process which might equally well, but less conveniently, be done by stirring the solution with a suitable quantity of the adsorbent and removing the latter by filtration.

It is essential to distinguish carefully between such adsorptive filtration and true chromatography. In adsorptive filtration a liquid is allowed to percolate

through an adsorbent arranged in the form of a column, cylinder, disc, or other suitable form. The process allows a separation into only two fractions—the filtrate which flows from the further boundary of the adsorbent and the material retained by the adsorbent. Chromatography is a different and much more versatile process ; not only may the composition of the filtrate vary, as, for example, when forming the so-called liquid chromatogram, but in addition the substances retained by the adsorbent, or equivalent materials, are spatially separated.

There are, however, several examples in the literature of the use of very large columns for truly chromatographic procedures. As already mentioned Urey used a column a hundred feet long in an attempt to separate isotopes. In the original separation of vitamin K, from alfalfa, columns containing several hundred pounds of material were used. The use of an adsorption column 14 metres long for separating hydrocarbons has been described. In Texas plant pigments are being separated commercially on columns of charcoal and streptomycin is commercially purified on columns of alumina. It is, therefore, apparent that chromatography on a scale large enough to be of industrial importance is quite feasible.

The difficulties in applying chromatographic methods to industry seem likely to be economic rather than practical. Various factors present themselves immediately. First there is the cost of adsorbent and solvent. The cost of the former may be prohibitive unless it can be cheaply and easily regenerated, and used almost indefinitely. In this latter respect ion-exchange adsorbents appear to be particularly suitable. Their initial cost is relatively high, but can be expected to fall through increasing demand. They can be used repeatedly if solutions to be passed through them are suitably prepared. There are also practical difficulties of control. Those who have worked with large columns in the laboratory will be well aware of the difficulty of maintaining uniform flow so that the boundaries are clearly defined and of regular shape and no channels make their appearance. This difficulty will be much greater with columns of a size suitable for manufacturing processes, and it will be necessary to develop both adsorbents of very regular granularity and means of packing them uniformly in large columns. Speed of percolation is also an important economic factor.

Interesting patents relating to adaptation of the chromatographic method for industrial use, have been granted (B.P. 585224 and 611080). In this piece of equipment, somewhat similar in principle to a device which I described some years ago for the rapid testing of adsorbents, the solution percolates radially through a hollow cylinder of adsorbent. The cylinder can, if desired, be rotated at high speed so that the fluid is forced through the adsorbent by centrifugal force. For this reason the machine has been named a chromatofuge. Alternatively the liquid can be forced through by suction or by application of pressure ; this method would probably be the one chosen for industrial work. The various fractions of the chromatogram can be separated either by collecting them successively as they flow from the outer edge of the cylinder or by removing the solid adsorbent carrying the different fractions in the same way as one treats a column of adsorbent in the laboratory.

British patent 611080 relates in part to a column which can be mechanically divided into sections to facilitate the separation of the various zones of a chromatogram formed within it. When the separation is complete the various sections can be slid to one side, their contents removed, and finally be refilled with adsorbent and replaced.

Medical Applications of Paper Partition Chromatography

by

Dr. C. E. Dent

Before going into any detailed applications of partition chromatograms I will deal briefly with a few matters of general interest. The unique feature of a partition chromatogram, as distinct from the classical Tswett type, is that if the theory of Martin and Synge is correct, it should

be possible to predict the rate of movement of a substance down the chromatogram with respect to the rate of solvent movement. This is because the rate depends only on the cross-section areas of the moving and stationary phases and on the partition coefficient of the substance between these phases. For many substances this has indeed been proved to be so although there are exceptions which underline the fact that other processes, such as adsorption, may also come into play. Nevertheless, whatever the mechanism concerned, the behaviour of a substance on a particular partition chromatogram is of the nature of a physical constant which can therefore be used as a means of identification, the specificity being comparable to that of a melting point. Hence it is likely that the greatest value of the new chromatography will be as a weapon to be used for qualitative analysis. It must not be ignored however that it can also be used for quantitative analysis and as a method of isolation of pure materials.

This stress on qualitative analysis has led to a rapid exploitation of its most simple form, that which uses pieces of filter paper on which various solvents are soaked past an area containing a small quantity of the mixture in question. Dr. Williams has reviewed this technique briefly but before dealing with its medical applications I will give some reasons why paper chromatography is becoming such an indispensable tool. Firstly, there is the comparative simplicity of the method. It can be carried out satisfactorily with entirely home-made apparatus. Secondly, there is the fact that the characteristic behaviour of a substance on the chromatogram is surprisingly unaffected by relatively large quantities of other substances which may be present. Hence the identification can easily be done using only a very impure product. It can be made much more specific when carried out on the ingenious two-way (two-dimensional) chromatograms, the method which is also known in the more colourful American language as the ' Two-way stretch.' When this is coupled with still further runs in other solvents and with spot tests on the paper, the identification of an unknown substance by comparison with a known one becomes completely reliable. For instance, the presence of γ-aminobutyric acid in most plant and animal tissue fluids was correctly shown by purely chromatographic means several years before being confirmed by actual isolation. It is as if the organic chemist's wildest dream had come true—perfect melting points obtained on a product only 1 per cent. pure! Another advantage is the ultra-micro scale of operation, which by the way, can be carried out with surprisingly few precautions against contamination. Many constituents of body fluids can never become available in more than μg. quantities. For instance, we have obtained exellent amino-acid chromatograms from the hydrolysate of a secretion which Dr. Kodani obtained by microdissection from the duct of the salivary gland of the larva of the drosophila fly. Thanks also to this, not only can fairly elaborate chemical syntheses be carried out entirely on the μg. scale, the final product being identified on the chromatograms, but also a larger scale chemical process or metabolic experiment can be followed throughout various stages by the chromatographic analysis of very many samples of absolutely negligible volume. The method is also of very general applicability, and we now know that almost any readily water-soluble compound can be analysed on the paper with the solvents now in current use, and there are novel modifications which are extending the field to include compounds soluble only in fat solvents. This already makes it applicable to many more substances than is a melting point. A further feature is that it lends itself admirably to studies using radioactive isotopes, since the areas of paper occupied by the labelled compounds can be detected by the usual counting devices or by simply pressing against a photographic plate. Finally there is the advantage that when analysing unknown mixtures for, say, amino-acids, one often has it thrust before one in a most provocative manner that the method can detect the presence, not only of what we might be expecting to find, but also of all the amino-acids present that we are not expecting to find. You note, in other words, one or more spots on the paper giving typical ninhydrin reactions but whose chromatographic behaviour cannot be matched by any known amino-acid.

One sometimes stumbles on these exciting 'unknowns' when one is least expecting them and occasionally in a most bewildering profusion. It is this that leads one to sense that nothing less than a new world of investigation is now being opened up with challenging problems in all directions.

I am sure you will now agree that we have available a method especially valuable for the investigation of medical problems. The great difficulty in medicine, and in any other biological subject, is that one is invariably presented with the need to analyse fluids which contain the most fantastic assortment of very many known and unknown constituents. As a result, most analytical methods are non-specific and it may take years of research to develop a method for detecting unequivocally, far less to determine quantitatively, the presence in plasma of commonplace substances, as for instance creatinine and fructose. This is certain to be much easier in the future.

I will now turn to consider some aspects of amino-acid metabolism. The application of paper chromatography to the accurate qualitative and rough quantitative analysis of body fluids has now been thoroughly worked out. There is no particular difficulty in analysing samples of urine, plasma, sweat, saliva, cerebro-spinal fluid, ascitic fluid, tissue extracts, etc. The result of each analysis is a sheet of paper displaying 20 or so coloured spots whose position accurately portrays their identity and whose colour strength roughly indicates the amount present. By merely looking quickly at the very different patterns from say, equal volumes of simultaneously obtained samples of plasma, urine, and cerebro-spinal fluid, the conclusion is quite unavoidable that these fluids are not derived from each other by simple physical processes such as diffusion or ultra-filtration but must involve active secretory mechanisms, mechanisms which deal quite differently with different amino-acids. People had to work and argue for years to prove this by other means. It is especially interesting to study tissue fluids since it is from these that the synthetic processes of the cell draw their materials. The individual amino-acids in the intracellular fluids are present in much higher concentrations and show a different pattern from those in the extracellular fluids in which the tissues are bathed.

Some diseases show characteristic changes of amino-acid pattern in the body fluids. For instance the body fluids in phenylketonuria, a severe form of mental deficiency, are characterised by the presence of a greatly (up to 20 fold) increased concentration of phenylalanine, the other amino-acids remaining practically unchanged. Such an enormously increased concentration is very readily detected on the chromatograms and it is therefore possible to diagnose this disease with certainty from the analysis of a small drop of urine without even seeing the patient.

There are also interesting changes in amino-acid levels in liver disease. For instance, in the fatal form known as 'acute yellow atrophy' large rises in the concentrations of most of the amino-acids present occur in plasma and urine; indeed this finding, also readily detectable chromatographically, is of value as a warning of the seriousness of the condition.

Another group of conditions is distinct from the two examples above in that a grossly increased excretion of amino-acids occurs into the urine even though the plasma level continues to be normal. Clearly in such cases, it is the kidney which must be blamed for the changes found. An additional interesting fact to be noted is that all such conditions appear to be hereditary. In some cases the changes are found in people who are apparently quite normal. Often, however, serious disease is associated with it, e.g. in cystinuria where there is a tendency to the formation of kidney stones, in the Fanconi syndrome—a severe bone disease, or in hepato-lenticular degeneration—an incapacitating and slowly fatal nervous disease. In the Fanconi syndrome we believe that the urine abnormality is present some time before the onset of bone symptoms. Indeed in a recent case, where a family was investigated (with the help of Dr. H. Harris), we analysed chromatographically the urines from over 40 relatives. This led to the discovery of three further people with the increased urinary amino-acid secretion but whose bones were apparently healthy. We are watching these people closely so as to be ready with the treatment if any mischief

develops, as we think it may in the passage of time. Further consideration of this group of diseases leads to an interesting problem. The change in kidney function whereby amino-acids are allowed to leak into the urine in excessive quantities is only rarely encountered, it is a freak phenomenon. Why then is it that such a similar change occurs in a few diseases so completely different from each other as the three mentioned above? There must be a common link which is entirely unsuspected from what we know already about these diseases. We are very perplexed. We have theories, of course, but none are plausible enough to be owned up to in public.

In conclusion I must introduce a cautious note. While for research purposes paper chromatography is continuing to show unbounded promise, nevertheless as a medical diagnostic tool in the amino-acid field it is still useful only in the case of a few rare diseases. It is anybody's guess whether it will or will not be much more valuable when fully exploited in this and all the other directions in which we already know that it can be applied. My own guess is that it will.

Inorganic Analysis by Paper Chromatography

by

Dr. F. H. Pollard

Recent developments of chromatography as applied to the separation of inorganic compounds on filter paper and cellulose columns are likely to have revolutionary effects on the whole field of chemical analysis. It will be possible not only to avoid long and tedious laboratory work, but also to carry out analyses on minute quantities, hitherto impossible. The technique is simple, and, given the right conditions, is capable of being performed by routine workers, providing they are neat and careful. The method has obvious applications to geology for the analysis of minerals, to agriculture for the detection and estimation of 'trace' elements in soils and plants, to metallurgy for the quantitative analysis of metals, and indeed to all those fields of science where chemical analysis is essential.

Interest in the use of filter paper as a means of separating metallic derivatives dates back to about 1890, and among the workers of that period was Goppelsroeder, who in his book *Kapillaranalyse* (1901), describes a large number of separations of both organic and inorganic compounds on filter paper. His method consisted essentially of dipping one end of a piece of filter paper in a solution of inorganic salts and allowing the liquid to diffuse by capillary action. This led to the separation of compounds into narrow bands close to the liquid front. Such zones are not always very distinct, but it was possible, nevertheless, to distinguish bands belonging to different compounds. This technique, with various modifications, has long been used in micro-chemistry for the identification of certain cations.

The great success of the partition methods of Martin and Synge in the field of organic chemistry for the separation of intimate mixtures of amino-acids, sugars, carboxylic acids, etc., in microgram quantities, led a number of workers quite independently, to investigate the application of these procedures to inorganic compounds. Linstead and co-workers at the Chemical Research Laboratory, Lederer at Sydney Technical College, Australia, Larcourt and co-workers at the University of Brussels, have all made important contributions which lack of space makes it impossible to describe in detail. In contrast to these workers, we at Bristol set out to deal with the problem in a general way in order to develop a scheme which could be applied to the analysis of a large number of different cations and anions, without reference to any particular group of radicals or without any previous chemical separations into groups. Initially we paid most attention to those cations and anions normally associated with the ordinary qualitative analysis tables, but we are now rapidly extending our methods to the identification of other metals, such as Ti, V, Mo, U, Th and Ce, and also to quantitative micro-estimation.

The apparatus and general procedure are based on that of Martin and Synge and will therefore be generally familiar.

In general, we favour the downward movement of the solvent (descending

chromatography) using a strip of paper wide enough for the chromatogram to form without interference from the edges of the paper, that is, about 1½ ins. for each spot. Provided that adequate precautions are taken to keep the paper strip reasonably taut, the upward movement of the solvent mixture (ascending chromatography) can yield quite a good chromatogram. Movement of ions is conviently expressed in terms of their R_f value, which measures their rate of movement relative to the liquid front.

The minimum quantity of any cation or anion which can be chromatographed and detected is partly determined by the sensitivity of the reagent used for its detection. It is well known that many analytical tests are increased in sensitivity when performed on filter paper, and this adds to the chance of detecting minute amounts. For our purpose we needed a general reagent which would detect the position of as many cations as possible, just as ninhydrin is used universally for the detection of amino acids. Of the very large numbers of reagents we have examined, the following have been found to be most generally useful :—

(a) ammoniacal hydrogen sulphide solutions for those cations which give coloured sulphides, and
(*b*) a mixture of kojic acid and 8-hydroxyquinoline in alcohol, which gives coloured spots with some cations but reveals the position of the majority of them as fluorescent or dark spots when viewed under the ultra-violet lamp.

The fluorescent reagent is at least five to ten times as sensitive as hydrogen sulphide, where circumstances permit a comparison to be made ; for example the smallest amounts of cadmium that can be detected are :

using H_2S, $2{\cdot}5 \times 10^{-6}$ gm. ;
using fluorescent spray, $0{\cdot}05 \times 10^{-6}$ gm.

Since the inorganic compound is spread over a larger area after it has been chromatographed, it is found as a general rule that the minimum quantity of a cation which can be successfully analysed is an amount corresponding to about four times the sensitivity of the most sensitive detecting reagent.

Unsatisfactory chromatograms are obtained if the paper is overloaded, and as a maximum amount for optimum results, a quantity equivalent to 0·02 c.c. of a 0·1N solution of a cation is satisfactory.

For many of the cations the evidence obtained from their position on the paper chromatogram and their behaviour with the two general spray reagents is usually sufficient to characterise them. Wherever any doubt exists, however, it has been observed that many of the normal microchemical tests can be adapted to settle the matter, for example, rubianic acid for copper, cobalt, and nickel ; dimethyl glyoxime for nickel ; rhidozonate for calcium ; zinc uranyl acetate for sodium ; potassium chromate for lead and silver.

We are now investigating a system of confirmatory tests for analytical work, but this is not quite ready for full publication, though the results are very promising.

The choice of solvent as the mobile phase is of primary importance in this work, and already a large number of different types have been described, including alcohols, ethers, ketones and heterocyclic compounds like pyridine. Their suitability has depended on the particular group of cations to be separated, but the use of any one particular solvent may be limited to quite a small group of cations. It is here that our work has differed materially from that of other workers, for we have limited ourselves to relatively few solvents which are readily available, and have tried to modify conditions to make them suitable for the separation of a wide range of cations.

Our selection of solvents has been based on the two following principles :—

(a) The use of a suitable solvent containing a small quantity of a reagent which will form with many cations complexes that are likely to be at least partially soluble in the organic solvent and water, and
(b) the use of solvents with which the cations themselves will form complexes that are soluble in the solvent.

With these ideas in mind, we have investigated a variety of solvents and complexing reagents, but I shall only mention

those which have been found to be most useful. Our aim was to develop a scheme for general analysis irrespective of any previously known groups of cations or, for that matter, anions. Up to the present, the three following general solvent mixtures have been found to be most useful :—

(a) Butanol saturated with water mixture, containing benzoyl acetone (0·5 per cent.) for the movement of Ag, Hg^{+}, Hg^{2+}, Pb, Cu, Cd, As, Sn^{2+}, Sn^{4+}, and Fe.
(b) Collidine-water mixture for Ag, Cu, Cd, As, Sb, Zn, Mn, Co, Ni, Ca, Sr, Ba, Mg, K, and Na.
(c) Dioxan containing antipyrine for the movement of Ag, Hg, Pb, Hg, Bi, Cu, Cd, As, Sn^{2+}, and Sn^{4+}.

The extent of the movement of those cations which move in both solvents may be quite different, but this can be used to advantage, as will be explained later.

The separation of only one inorganic material from a large number of others is sometimes of interest, and in the course of our general investigations we have found a suitable solvent mixture which will isolate only As. There are a number of other special solvents for particular separations, for example, Zn and Cd by a butanol mixture containing collidine as a complexing reagent.

We have found that *p*H is a very important factor in successful separations, not only for the formation of complexes by the complexing reagent as the solvent mixture flows over the paper, but also for the prevention of hydrolysis of some salts. Thus, the *p*H of both the solvent mixture used as the mobile phase, and the initial aqueous solution of the inorganic cations must be rigidly controlled. The effect of varying the *p*H of the solvent mixture is well illustrated by the movement of Fe^{3+} using the butanol mixture as the mobile phase.

Generally speaking, the initial aqueous solution should be as concentrated as possible with respect to the cations, and at a *p*H of about 2. We favour nitrates or acetates as starting salts, and usually adjust the *p*H with a little dilute nitric acid. The anion originally associated with the cation in a mixture does not seem to be very important, unless, of course, it results in the production of an insoluble salt like lead chloride or barium sulphate. Some abnormalities have been noticed when phosphates, tartrates, arsenates, or large quantities of ammonium salts are present, but these effects have not yet been fully examined.

Using the three general solvent mixtures already described, we have found that a very large number of mixtures can be readily separated by modifying different procedures according to circumstances.

One-way separations

For certain groups of cations, a single one-way chromatogram will yield sufficient evidence for a complete analysis.

It is interesting that the separations are usually in agreement with predictions from the studies on the movement of single cations, though cases of displacement sometimes occur. Since complete dependence is not placed on R_f values alone, this has not caused any real difficulties, for we have always been able to identify the cation with specific spray reagents, and by running a mixture of known cations side by side with the ' unknowns.'

Where the amount of material is strictly limited, it is practicable to separate some cations with the butanol mixture, and then after washing with carbon tetrachloride and drying, to separate others with the dioxan mixture in the same direction. We have called this the ' one-way, two solvent ' procedure. Only a few separations performed in this manner have been carried out ; the method is capable of further development.

Two-way separations

The analysis of one drop (0·02 ml.) of solution can often be achieved by a two-way separation, one at right-angles to the other, often called ' two-dimensional chromatography.'

The positions of the cations after movement are usually in accordance with prediction from their individual movements in the two separate solvent mixtures, and are shown in the following slide.

It has been observed that Cu always has a higher R_f value in the second solvent (butanol) than would be expected, and Zn in some mixtures has a larger R_f value, probably due to the stability of the

respective collidine complexes. Sometimes there is also a tendency for the arsenic not to move in the collidine mixture.

In most cases tried, the separations cited above are sufficient for identification purposes, but it was thought advisable to see if further separation could be achieved by the use of the third solvent. For reasons which are not yet understood, dioxan was not satisfactory in the two-way, two solvent procedure, but from the limited experience gained with the two-way, three solvent procedure it has definite advantages here.

Two-way, three solvent.

First solvent—collidine ;
Second solvent—butanol, run at right-angles to the collidine separation ;
Third solvent—dioxan, run in the same direction as butanol.

The first two solvents moved the cations to the positions predicted ; there was no separation of Al and Bi, while Mg and Mn were very close together. When the third solvent was used, the Bi separated from the Al, while Mg, Mn and Cd moved to new positions more separated from one another.

Lack of space makes it impossible to give any further details here, but those interested may like to know that we have recently submitted two papers to the Chemical Society describing this work in detail.

It is hoped, however, that sufficient indication has been given of the lines on which this technique is developing and its great possibilities as a means of qualitative analysis. We have found that the separations which can be made on filter paper can be carried out on a larger scale with cellulose columns, and this opens up the possibility of performing analyses on larger quantities of material, or the purification of compounds, or even the preparation of inorganic materials.

Some descriptions of quantitative determinations have been given by other workers ; we have shown that it is possible, after separation on the paper chromatogram, quantitatively to estimate cations by the extraction procedure described by Hirst and Jones (June 1949) for sugars, followed by estimation of the extracted cations on the Spekker photometer.

Separations of anions

A number of suggestions have been made for the separation of anions. We have found that the solvent mixture is most successful when it is alkaline, and a mixture consisting of butanol, pyridine, and 1·5N ammonia (80 : 40 : 80) moved anions with the following R_f values :—

Movement of Anions

Solvent mixture, butanol, pyridine, 1·5N ammonia (80 : 40 : 80).

Rf values for anions

Cl' 0·24, Br' 0·36, I' 0·47, ClO_3' 0·42, BrO_3' 0·25, IO_3' 0·09, NO' 0·25, NO_3' 0·40, CNS' 0·56, SO'' 0·07.

Mixtures of the anions were tried and in all cases the movement and separation were almost the same as that for the individual anions ; the slight displacements observed, for example, with NO_3', Br', and I' tended to improve the chromatographic separation. We have frequently observed that anions and cations moved independently of one another.

Further work is in progress to develop a general procedure for the analysis of groups of anions.

In concluding, it must be pointed out that there are a number of factors which affect the separations, but their influence has, up to now, only been considered qualitatively. Thus, it is only possible to be guided by these qualitative general principles in predicting the possible separations, and in this sense the work must remain somewhat empirical until more is accurately known about the processes involved and their relative importance.

Finally, I must acknowledge the invaluable assistance which I have received from my colleague Dr. J. F. W. McOmie and from our students Messrs. I. I. M. Elbeih, A. B. Law, and H. M. Stevens.

Appendix

One-way, one solvent separations

Butanol mixture containing benzoyl acetone

0·5 g. of benzoyl acetone is first dissolved in *n*-butanol (50 ml.), and then shaken with 0·1N nitric acid (50 ml.). When equilibrium is attained, the upper layer is used as the mobile phase.

Mixtures actually separated

1. Ag, Hg and Pb.
2. Hg, As, and Fe, with one of the following :—Ag, Pb, Bi, Al, Cd, Mn, Co, Ni, Ca, Sr, Mg, K, or Na.
3. As, Sb, and Sn.
4. Cu, As, and Fe, with one of the following :—Ag, Zn, Mn, Co, Ni, Bi, Ca, Sr, Ba, Mg, K, or Na.
5. Pb, Cd, Cu, As, and Fe.
6. Hg, Bi, Cu, and Cd.

One-way, one solvent separations
Collidine mixture

2 : 4 : 6-collidine is shaken with an equal volume of 0·4N nitric acid, and when the mixture separates on cooling, the collidine layer is used as the mobile phase.

Mixtures actually separated

7. Pb and Ag or Zn.
8. Hg and Cu or Cd or Zn.
9. Bi and Cd.
10. Al and Cu.
11. Fe and Cu or Zn.
12. Co and Ni.
13. Zn, Mn, Co and Ni.
14. Ca, Ba, and Sr.
15. Mg, K, and Na.
16. Ca, K and Na.
17. Mg, Ca, K, and Na.
18. Zn, Mg, Ca, Sr, and Ba.
19. Mn, Mg, K, and Na.
20. Zn, Mg, Ca, K, and Na.

One-way, one solvent separations
Dioxan mixture

1 g. antipyrine is dissolved in a mixture of 100 ml. pure dioxan, 1 ml. conc. nitric acid, and 2·5 ml. water, and this homogeneous mixture is used as the mobile phase.

Mixtures actually separated

21. Ag, Pb and Hg.
22. Cu, Hg, and Bi, with Ag or Pb.
23. Al, Cd, Hg, and Bi.
24. Fe and Bi.
25. Cd, Hg, Bi with Zn, or Co, or Ca, or K.
26. Cu and Bi with Mn, or Ni or Mg.

Two-way, two solvent mixtures

First solvent mixture—collidine.
Second solvent mixture—butanol run at right angles to the collidine separations.

Mixtures actually separated

27. Cu, As, and Fe, with any of the following :—
    (a) Pb and Zn, or Mn, or Zn and Mn.
    (b) Al, Cd, and Mn or Zn.
28. Al, Cu, Fe, Zn, Ca, and Mg.
29. Pb, Cu, Cd, Fe, Ca, Sr, and Ba.
30. Bi, Cu, Fe, Co, Mg, K, and Na.
31. Pb, Cu, Fe, Zn, Mn, Ca, and Mg.

OUTPUT PROBLEMS IN HOUSE BUILDING[1]

by

DR. J. BRONOWSKI

DR. BRONOWSKI said that for the previous four years he had taken part in research in the building industry, as a member of what was the Chief Scientific Adviser's Division of the Ministry of Works, that he had left this work some months ago (to become Director of the Central Research Establishment of the National Coal Board), and what he had to say at this stage was in the nature of a swan song which closed his professional interest in the building industry. What he had to say was a personal summary for which the responsibility was his entirely. The address, however, gave him the opportunity of thanking old colleagues, particularly R. W. Bevan, and many others in the building industry who shared in the ground work on which his views were built. While these views were his own, their claim to attention was that they were based on a foundation of factual knowledge which had been established by others.

LET me go straight to the point of our own building research in the last four years. What were we trying to do? In general terms, we were trying to raise the operational and the economic efficiency of the building industry. How were we trying to do it, and did we succeed? Here my answers are again my own; what follows is what I thought we were doing; and it is this.

We thought it reasonable to look at each of the traditional operations and each of the traditional components which go into building a house, and to see whether they might not better be replaced by a process or component which was not known 50 or 500 years ago. Did we succeed? I think the short answer is to be found in the most recent official publication which is meant to help those building houses. At the end of last year the Ministry of Health published a booklet of 100 pages or so for this purpose, which it called *Housing Manual 1949*. This book contains seven chapters, and there is one chapter, the last, which bears the gratifying title 'New Methods of Construction.' You may judge the importance which all concerned attach to new methods of construction when I tell you that this chapter, this complete chapter, consists of one page of print.

In studying the operations of building, we were, I think, all struck by the prodigious amount of handling which they involve. Builders use few machines, and if they are small builders there are, in fact, almost no machines made which suit them. We therefore set ourselves to design and develop several small multiple-purpose machines for the small builder—things like tractors, diggers, concrete skips and so on. Did we interest anyone in them? Again you must judge for yourselves; I will quote the facts. A year ago we finished a pilot survey of house building in 1947 and 1948 in 8 of the 12 regions of Great Britain. In this we surveyed a carefully stratified sample of building sites in these regions, and the statistical techniques used to draw general conclusions from this sample are themselves of interest because they are new to such industries as building. But I do not want to stop at techniques; I want to quote some results, which have been published in summary form, and used in part by the Girdwood Committee, and which I hope will soon be printed in a full report. On sites of 20 houses completed about the end of 1948, the average cost of each house was £1,215; the range of variation

[1] Paper read to the Engineering Section at Birmingham, on September 1, 1950.

can be judged by this, that just over 50 per cent. of all houses lie within £100 above and £100 below this average. Of this cost (and it is a cost—it does not include profit and certain overheads) the material cost £735 and the labour £390. The charges for all machinery and plant used on the site, including picks and shovels and concrete mixers and even lorries and scaffolding—all this amounted to less than £30 per house. This is the extent to which house building has been mechanised : that it spends £30 on plant for each £390 of wages.

You see that I do not take a very heady view of our success. I think that the practical impact in four years of the work in which I took a passionate interest has been, alas, very small. If this were all I had come to say to-day, I would have been decently ashamed and held my peace. But of course the reach of research is greater and is deeper than this, and this is true of industrial as much as of academic research, and is true of operational research such as we were doing. I do not know whether the industry will in time take to heart the practical changes which we proposed ; I hope it will. But so far as we, the research workers are concerned, we have learned in those four years to assemble a picture of the industry which can be profoundly helpful to others, in all industries. We have learned to understand the structure of the industry. The figures are familiar enough on paper ; I knew them four years ago. They are not secret and they are not much more inconveniently hidden than other official statistics. I am quoting nothing which you could not find out for yourselves with a little patience—about four years of patience. But the total picture is something immensely more vivid than the figures ; it is the living structure of the industry. This structure, we now understand, dictates what can and what cannot be done. You can introduce new methods only if you fit them to the structure, and if from the outset you have clearly in mind how the structure is to be changed step by step to keep pace with the spread of the new methods.

The building and civil engineering industries, which are usually classified together, employ about 1·4 million men, skilled and unskilled. In addition, the building materials industries employ over 200,000 men ; so that the total is between 1·5 and 1·75 millions, which is nearly 7 per cent. of our whole working population. Except during the two wars this percentage has not changed much in the last 50 years ; but such change as there is has been upwards. That is, leaving aside boom and depression fluctuations, the long term trend has been a further rise in the proportion of our manpower which we use for house and other building, amounting to an increase between 1 and 2 per cent. of the total manpower over the last 50 years.

The internal craft structure of this labour force has been even more stable. Let me give you an extreme example and quote the totals and percentages of skilled men in England and Wales on the last date before the first war, that is July 1914, and on the first date after this war, that is July 1946.

TABLE I.

Building and Contracting—Craft Composition. England and Wales.

	July 1914	Per cent.	July 1946	Per cent.
Bricklayers	73,671	25·5	87,210	22·1
Masons .	34,381		10,710	
Carpenters & Joiners	126,345	29·8	125,450	28·3
Slaters and Tilers	4,154	1·0	14,630	3·3
Plasterers	19,479	4·6	28,220	6·4
Plumbers	33,009	7·8	46,970	10·6
Painters .	132,479	31·3	129,680	29·3
	423,518	100·0	442,870	100·0

This is not a fair example, because in July 1946 the industry had not quite settled down to its post-war total. The numbers of all craftsmen which I have quoted have risen since then by 20 per cent. ; but the percentages of the different crafts remain the same. You see that these proportions have hardly changed since 1914 and before ; and such small changes as there have been have actually increased the proportion of men working at the jobs we should most like to mechanise, such as plasterers and plumbers.

The structure of the building industry is equally remarkable if we look at it firm by firm. Here is a table of the size of firms or establishments, measured by the number of people employed there, first in the building industry and then, for comparison, in the mechanical engineering industry.

TABLE II.

Size of Establishments in 1935.

Size of firms or establishments (by numbers employed)	*Building and Contracting.* Firms		*Building and Contracting.* Persons employed		*Mechanical Engineering.* Establishments		*Mechanical Engineering.* Persons employed	
	Number	*Per cent.*	*Number*	*Per cent.*	*Number*	*Per cent.*	*Number*	*Per cent.*
1–10 . . .	64,028	88·1	243,983	32·7	4,573	59·3	22,369	4·9
11–24 . . .	3,624	5·0	63,647	8·5	971	12·6	16,166	3·5
25–49 . . .	2,650	3·7	90,774	12·2	782	10·2	26,830	5·9
50–99 . . .	1,442	2·0	98,527	13·2	542	7·0	38,027	8·4
100–199 . . .	583	0·8	79,670	10·7	365	4·7	51,719	11·4
200–299 . . .	179	0·3	43,607	5·8	153	2·0	37,173	8·2
300–399 . . .	72	0·1	25,134	3·4	95	1·2	32,472	7·1
400–499 . . .	34	0·0	14,575	2·0	48	0·6	21,510	4·7
500–749 . . .	36	0·0	21,176	2·8	65	0·9	39,943	8·8
750–999 . . .	11	0·0	9,618	1·3	46	0·6	39,363	8·6
1,000–1,499 . . .	16	0·0	19,504	2·6	35	0·5	42,408	9·3
1,500 and over . .	15	0·0	36,046	4·8	31	0·4	87,200	19·2
Totals	72,690	100·0	746,261	100·0	7,706	100·0	455,180	100·0

In addition, it is likely that many small building firms were missed in the Census, and an estimate of the number of persons employed by those firms is 100,000.

These show at a glance how different is the distribution in the two industries. The building industry is dominated by small firms. Mechanical engineering is more evenly spread among its firms, and the main weight lies in the central ranges, say between 100 and 200 men in a firm. But even this does not tell the whole story. The tables happen to be those for the year 1935 for which the returns from the two industries exist in a comparable form. In 1949 the number of building firms which were registered as having no operatives at all was 70,000. This is not the mark of a modern efficient industry.

All this would be less important if the building industry were small. But it is one of our major industries : in 1948 the country's building of all kinds accounted for £1,181 millions, or nearly 60 per cent. of gross fixed investments in Great Britain. Yet the average capital resources of each firm are minute. The building firms of the country have a capital which averages between one-quarter and one-third of a single year's turnover, and which incidentally is remarkably constant at this proportion for all sizes of firms. When we remember that most of this is sunk in the materials on current building, it is frighteningly small. This is the reason why builders have headed the list of bankruptcies year by year, ever since records have been kept.

This picture which I have drawn, of a very stable craft structure and of a mass of small firms with a tiny capital, has still to be rounded out in one respect. There are industries—electrical engineering is one—in which as we go down the scale of size to the smaller firms, we meet a growing percentage of firms which specialise in some single product or process. If anything the opposite is true in the building and civil engineering industry. There are few specialists, and these few are to be found almost alone among the larger civil engineering contractors. When we get down to the small firms, the variety of work which such a firm is willing to try becomes bewildering. Indeed, the smallest firms concentrate on repair work,

which is the least specialised of all building work. This lack of specialisation among small firms is, I believe, the heaviest handicap which the industry carries.

It is part of this picture that so much of the labour in the building industry is unskilled ; more than one-third of work on the site always has been and still is done by unskilled manual labour. It has not been sufficiently remarked that changes in output are not the same in skilled and unskilled trades. If we were to make a list of the industries of this country and arrange it according to the percentage of unskilled labour employed, then we should find that the greatest ups and downs of productivity between good and bad times occur in the industries which employ most unskilled labour. The output of the building industry remains low to-day by pre-war standards and by the standards of other industries, because its content of unskilled labour is so high. It is a familiar saying in mechanical industries that the pace of the craftsman is set by the machine. Almost the only machine employed on most house building sites (apart from that wonderful old battle-wagon, the concrete mixer) is the unskilled manual labourer. He is setting the pace of the craftsman.

I have already expressed this fact in money terms ; let me put it now in operational terms. The total dead weight of the materials in a house is 130 tons. But the weight actually handled exceeds 630 tons. Nearly half of this, about 260 tons, is handled by the human digger, concreter and general labourer ; the greater part of the remainder is handled by the bricklayer. During his working hours, a bricklayer is actually handling bricks and mortar at the rate of more than a quarter of a ton an hour ; and the general labourer at the rate of well over two-thirds of a ton an hour. And all this is handled by skilled and unskilled men alike with almost no mechanical aids. Again let me invite you to look at the figures. In this country the average number of horse-power employed per man in all manufacturing firms now is about 2·5. The number of horse-power in the building industry, which handles these very large bulks of materials, is 0·5 per man. I have searched the records of 10 or 20 of our manufacturing industries, large and small, in an effort to find one which employs markedly fewer horse-power per man than does the building industry, because I wanted to be able to quote at least one to you. And I found exactly one : it is the fish curing industry. By way of comparison, I estimate that the agricultural labourer in this country commanded on an average about 1 mechanical horse-power per man before the war, and now averages 3 or 4 horse-power per man.

This weight of tradition in its structure makes the building industry particularly inflexible in response. I have no doubt that in introducing new machines and new kinds of houses, we underrated the natural inertia of an industry so ponderously and anciently integrated as this industry. Yet the building industry has had periods of relatively high efficiency. It is usual to compare post-war output in each industry with the output in 1938 and 1939. It happens that this comparison is less favourable to the building industry, because the 1930's were the very peak of productivity in house building ; nothing like them had been seen before. It was during this time that the ancient objective of one house per man-year was reached and surpassed. In the 1920's costs had been high and output low, so that output did not reach as much as three-quarters of a house per man-year. It is doubtful whether the building industry reached the 1914 level of 0·8 to 0·9 houses per man per year for 12 years after the first war—that is until 1930. And there is at first sight no striking improvement in technique in the 1930's to account for the steep upward movement in output then. Certainly it was not produced by the threat of unemployment ; the most productive time came after 1933, precisely when employment was rising. What were the causes which in the long run raised efficiency so markedly between the wars ?

The separate causes, which were numerous, can be traced back to a single underlying change : the growth of standardisation in the components of a house. At the beginning of the century the house was built on the site, almost to the last detail ; the joinery was cut there, the windows were glazed there, the fire-places were built there and even the man-hole

covers were made on the spot. The major change between the wars was that one after another of these components came to the site ready made : man-hole covers, drainpipes, fire-places, windows and doors. A growing amount of the plumbing came in standard units. In 1914, every ceiling was still plastered by hand. In 1939 there was hardly a new house in the country whose ceiling had not come from a factory as plaster-board.

These changes did not come overnight ; I do not think that they would have been effective if they had done so. On the contrary, it is my point that they were absorbed piece-meal into an industry which began by looking at each one of them askance. Builder and architect would have risen in anger in 1920 if they had been told that the way to make better houses more quickly is to use more uniform components. Yet by 1939 no architect was outraged and no joiner downed tools if they were asked to fit metal windows. The small factory-made component in a size which could be man-handled had made its mark in the industry. Unhappily, mechanisation had not.

This growth of factory standardisation had an influence also on the design of the house. We tend to forget that the house with a parlour and three bedrooms was not a pattern before 1914, and indeed no pattern existed then. Four million houses were built between the wars. No doubt many of them were ugly and too many of them were alike. But they did create for themselves, by a process of their own evolution, a pattern which was suited to the materials used and to the resources of the small builder ; and which raised his output strikingly in the later years when he had learned to carry out the steps in building them in a precise and dove-tailed order.

I want to underline the last point. In the 1930's the rise in building productivity was at least as high as in any machine-using industry. This did not make the building industry the equal of the machine-using industries ; that would have been too much to expect. After all, the machine-using industries had made their great step forward in the Industrial Revolution ; but the Industrial Revolution and the nineteenth century passed the building industry by without leaving a mark. But in the 1930's, there were changes in the building industry which might have had, if time allowed, something of the force of a revolution. The changes sprang from a standardisation of small house components before they reached the site. They induced a pattern of house and of house building, a plan of the progress of building on the site step by step, which had far-reaching effects. This plan in turn brought with it the use of the building sub-contractor : a small team of specialists who came to do the brick laying by contract, or to set the fire-places, to hang the doors or to tile the roofs. There was for a short time a great growth in the division of labour on a building site, which was absent before and has not returned since. The 1930's were in fact among other things the heyday of the sub-contractor. The sub-contractors were small firms which were learning to specialise. And in this change of emphasis, this move towards the small *specialist* firm, the structure of the building industry was then evolving of itself towards a new form. The war put an end to this evolution and took the industry back not to the 1930's but to 1920.

Now that we have grasped this historical background, what can we learn from it in our present troubles ? There seems to me to be a number of lessons. First, we must take account of the way in which the industry is organised. It is no use expecting an industry of more than a million men to learn overnight how to build the kind of house which indeed apes the appearance of the Englishman's semi-detached castle, but which neither in its structure nor in its processes bears any relation to the traditional brick house. In fact, I count it a remarkable achievement to the industry that of nearly 700,000 permanent houses finished on April 1, 1950, more than one-fifth are permanent houses of non-traditional construction—that is they are not built of brick. It is a remarkable achievement, but given the structure of the building industry it was bound to be an uphill and costly achievement. At the end of it, unhappily, the house not built of brick is disliked by the builder, the official and the public.

It is sometimes held that the permanent house made of other materials than brick —which usually means of concrete slabs or larger concrete units or of poured concrete—is losing ground because it is a dear house. I do not think that this is an intelligent judgment. I have already referred to the findings of our pilot survey on brick houses, which show that the materials there cost on an average in 1948 £735 (the range for 50 per cent. of houses covering just over £50 above and £50 below the average) and the labour costs were £390 (the range for 50 per cent. of houses again lying a little over £50 on each side). Moreover, in our sample survey we did for the first time use a technique which isolated the statistical trends to which these averages were subject over the two years covered by the survey. This showed that labour costs were then falling at the rate of £10 a year, even where no incentive bonuses were paid ; and this in spite of some rise in wages during that time. But this gain was quite wiped out by a rise in the cost of materials at the rate of £60 a year. Something of this disproportion has gone on since before the first war, so that the ratio of the costs of materials to labour in a house has risen in the last 40 years from less than 1·5 to 1 to its present figure of nearly 2 to 1.

In our two published studies of houses not built of brick, we showed that the better types of these houses did make large savings of man-hours on the site. There are at least four of these houses which, our work shows, can raise output once again to that longed for and long vanished target of one house per man-year. And there is one house, and it is an excellent house, which is actually saving 40 per cent. of man-hours on the site and reaching an output of 1½ houses per man-year. But in the very nature of things, with the building industry organised as it is, this saving in labour implies a rise in costs, because the main burden of costs rests with the materials that go into a house, and particularly the better finished materials. At the moment, with no single non-traditional house organised for continuous large-scale production, every penny which you save on the £390 of labour is pretty sure to cost you twopence on the £735 of materials. To criticise the cost of non-traditional houses is only to lay bare the failure to rationalise the manufacture of their materials and, more far-reaching, of all housing materials.

I myself would say that the various concrete and other houses carry a heavier handicap, and that is that they are out of step with the present structure and capacity of the building industry. In designing them I am afraid that no attempt was made to design anything but a set of factory-made walls to enclose the same space that the brick house had slowly evolved between the wars. But that evolution was as much a matter of the stages in the building of the house as of the space enclosed, and these stages are quite lost in the non-traditional house. Moreover, all the concrete houses call for the handling of larger and heavier units, and it is precisely in the mechanical handling of materials that the builder on the site is so backward. As a result, only a fraction of firms, and these the larger firms, can hope to tackle non-traditional houses in reasonably long runs.

My criticism here is that the concrete house is a copy of the brick house, and that you do not suit the house to the firms and the labour which are to build it by copying the mere appearance of the kind of house which they are accustomed to build. I will go further and say that the present designs of concrete houses are immensely wasteful because they bear no relation to the materials being used. We are simply stamping out, pouring out or casting from the new materials boxes to look as like the familiar brick boxes as possible. As a result all these houses contain far more partitions than they need, and even their outside shell is far stronger than it need be. House building in this country for at least 30 years now has suffered from the rigour of our bye-laws, which lay down standards and quantities which even the improved materials of the brick house have long outgrown. We have been making all our houses too strong and therefore too dear ; look at the chimneys and the outside pipes of any brick house. We have never learned the lesson of the motor car industry, that it is possible to carry the family safely in something less than a tank. But if this is true

of the brick house, it is many times truer of the concrete house. I mentioned one of them, which saves 40 per cent. on site man-hours. One way in which it does this is to have a roof slab in one solid piece ; but in deference to public taste, this slab is now to be embossed with a curly pattern which is intended to reassure the passer-by that it is decently covered with tiles.

These new houses offered us an opportunity to open up the space inside the house and to design quite a new plan. It should have been possible as a result to simplify and cheapen the heating, ventilation and internal fittings. Above all, it would have been possible immensely to reduce the amount of interior finishing which the house requires. This opportunity we have quite missed. The non-traditional house is losing ground for larger reasons of which I have already spoken, and which derive from this, that it has not been fitted to the capacities of the industry. The backwardness of the inside design shows the same obtuseness. I am afraid the conclusion is that few of the non-traditional houses have been designed at all.

I have come in the last paragraph upon what is I think one of the two or three outstanding problems of house building : the problem of what are called finishes. You will have noticed in the figures of skilled craftsmen which I quoted at the beginning of my talk that there are and have always been far more carpenters and joiners in the industry than bricklayers, and at least as many painters as carpenters and joiners. It is not the shell of the house which absorbs the site labour ; the whole shell, including walls, party walls, and inside partitions only accounts for about one-third of the site man-hours. No, it is the other work outside and inside the house which takes the time, and outstanding there, to this day, is the joinery and the painting and the plastering. Yet we found that most non-traditional houses spent their effort on the shell, and were content to follow traditional practice on the inside finishes.

Let me stop for a moment to take stock. Is the non-traditional house a good house ? Certainly ; it is quite as good as the brick house. Can it be made better ? Yes, if it breaks away from the brick house. But it must stop being such a conventional house. The word ' non-traditional ' should mean ' unconventional ' ; at the moment it means the opposite. And the stress in unconventionality should lie on the inside of the house, particularly the finishes. There is a great gain not only in site man-hours but in the total labour content of the house to be won from this fabrication in ready-made large panels, inside as well as out. If you have the right firm, on the factory and on the site—both are equally important—then you can save 40 per cent. of man-hours and at least compete in costs by making your house of large panels.

But in the nature of things, this is a solution only for large firms, well organised, with good mechanical equipment on the site, and commanding the large reserves of capital needed to run their own factory production in competition with the building materials industry. These firms, and these alone, could make a success of the large panel house. But what we have forgotten in our policy is that these large, mechanised, well capitalised firms are a mere handful in the industry ; I doubt if there is a handful of them. For the bulk of the industry, this is not the solution. Indeed, it is at odds with the structure and tradition of the industry ; and backward as these are, it is my belief that we shall raise the industry only by encouraging it to evolve itself. There is at present a head-on clash of interests between building with the old materials and building with the new materials. As a result, neither form of building is strikingly efficient and the new materials are losing the battle. No such clash and no battle should exist.

How are they to be avoided ? The answer is, by using the new materials in a form which the industry as it exists can handle, and to which it can in time adapt itself perfectly. The way to do this is to continue the technical changes which, though they ran under the surface, transformed the industry between the wars. That is, we should use the new materials to produce fairly small factory-made units which can be used in every kind of house. The ready-made doors, windows, stairs,

cupboard fronts, fire-places, wooden mouldings and plaster-board came into use between the wars. We should set ourselves now to make finished interior panels in small units to take the place of all inside plastering. If intelligently designed, they might go further than merely to cover the inside partition walls, and actually be made to take their place in strength and insulation. We should set ourselves to make floor and roof joists of other materials than wood—for example, of pre-stressed concrete—which can be assembled on the site in standard units without cutting. Lighting, heating, hot water systems, plumbing, kitchen fittings, and cupboards should all be made to-day in standard and self-contained units of a kind whose arrangement could be varied, yet which could be put into a house with no more special structural preparation than is now made for the bath. Floors could be assembled from standard slabs. Bricklaying could be greatly speeded by using ready-made corners. Every new house now has a large outhouse, and since this is a profitable structure, builders will no doubt be reluctant to let it go. Yet it would be a simple, substantial and pioneer contribution to the industry if we designed units of wall and roof slabs from which all outhouses could be assembled.

You will notice that the direction which I should like to see is in some ways the exact opposite to that which the non-traditional house has taken. The non-traditional house has tried to cut down the proportion of skilled labour which is needed to put it up on the site. But if my advice is followed and more and more factory-made units are provided to be assembled in their own way in each house, the building industry will need more precision work and quite as many skilled men as now. Among other things, it will need to work in multiples of agreed and standard dimensions. I do not think that this is a bad thing. I do not think that skilled labour is dear ; in every industry, skilled labour is cheap when we measure it in units of output, and unskilled labour is dear. So I am quite deliberately proposing changes which cut down not skilled but unskilled labour in house building. In particular, more skill will have to go into planning and progressing the site work ; and this again is a reform which is overdue.

These changes should not stop at new components. We need to take advantage of the existing organisation of the building industry ; but we need to direct it towards more specialised application. Let me turn again to the findings of our pilot survey. Incentive schemes were introduced into the industry about half-way through the time covered by the survey, so that we were able to study their effects in the second year. We found that where good incentive schemes were worked, which were well related to the true output of individual teams, each £1 paid in incentive saved well over 10 man-hours, and actually reduced the total cost of the house by at least another £1. We found that the site which had an extra pair of houses on it equally saved at least 10 man-hours per house, and more than £2 per house in total cost. And this was particularly true on the smaller sites—the average size of a site in the whole country is still only 7 or 8 pairs of houses, which is below the best size for the firms employing 50 men or so. Now these time and money savings do not, I think, arise simply because a bonus is paid or an extra pair of houses is built. They derive at bottom from the better running of a site when there is an interest in incentive and in planning. Modest as these gains are in the units in which I have expressed them, they would in fact suffice, if fully applied, to raise output on the traditional brick house by 20 per cent., and this even in the absence of any other improvements. This would carry us back to output on the eve of the war, the peak of the building industry.

But they could in fact be planned to yield a greater gain than this. I have said that at bottom I attribute them to better planning, which means to greater specialisation and a better planned and progressed sequence of operations. In my view, the real tragedy of house building since the war has been that it has not recovered the movement towards specialisation by small men which was at the flood on the eve of the war. If incentive schemes are to continue to do as well as they began, it must be by offering the same attraction to specialised work as was

offered to the sub-contractor before the war ; for of course the essence of the sub-contract was payment by results. There are now a great many operations which on a small site are still carried out by unskilled labour, which could be mechanised if the necessary machines could be used full time. The digging of foundations is such an operation ; you can make a small machine to do the work at an overall cost, including repairs and capital charges, which is half that now paid to navvies. But what small firm is going to pay £1,000 for such a machine if it is only going to dig 10 pairs of foundations a year? The same difficulties existed in agriculture and they have been overcome, for instance by sharing single-season machines like combine harvesters among a group of farmers. Farmers in Britain in the last ten years have increased their tractors fourfold and their combine harvesters twelvefold, while building has stood still. In the building industry the same end could be reached by encouraging one or two small firms in each area to undertake sub-contracts for all foundations there and by ensuring work for them all the year round. The same could be done for concreting, and the cost again halved. It could be done for much of the joinery operations and finishes which I should like to see turned into a skilled assembly of factory units. I want to see the mass of small firms progressively turned into specialists in some single operation—foundations, shell, finishes and the construction of the roof.

Here then are my two proposals for using the present structure of the building industry to the full, and at the same time to give it the opportunity to evolve a new structure at its own pace. The first asks us to look at the house afresh, not as a copy of the brick house, but as an assembly of structural functions for which we have not yet designed the best components in modern materials. The effect of this kind of unit design on the building materials industry would itself be profound and healthy, because building materials, while they have succeeded better in escaping the public eye, are at least as much to blame for housing difficulties as is the man on the site. Second, and coupled with this, I want to see the operations of the man on the site broken down into more specialised units, and taken over as far as possible by small firms doing that work on all sites in one area.

Would these two devices really raise output steeply ? I believe that they would raise it within one or two years at least to the level of one house per man-year. And this is a much higher level than it was in 1930, because the house is now almost 30 per cent. larger, better fitted and more substantial than it was then. But beyond the next year or two, I believe that this is the direction which the building industry must take for its own evolution, if it is to cease to be a cross which the nation bears and to become self-supporting. For let us make no mistake about it, housing is not self-supporting to-day. At 2,600 man-hours per house (and with 25 per cent. of houses taking well over 3,000 man-hours per house) at a cost of over £1,200 before overheads, profits, land, roads and drains are paid for, we neither build enough houses nor are we making them economic.

In 1900, a house and a medium-sized motor car cost the same, about £300. In the 1930's the house had gone up by 50 per cent. and the car had gone down as much. To-day, the disparity is as large or larger, if we exclude the purchase tax on the car. And we are not subsidising cars ; we are subsidising houses. At the present rate of output of about 200,000 houses a year, it will take us the best part of 50 years to keep up with the population which is still growing, and to make up well over four million houses which need to be replaced now or within a foreseeable time. At the same time, each house we are building is costing the nation by way of subsidy at least £20 per year—a total of four additional millions with each year of house building. This is not a new problem ; working class houses have seldom been built at an economic rent at any time in the last 50 years, and probably the last 100 years. But it is not, I think, a state of affairs with which we should be content. I believe that the proposals which I have made are the logical steps to help the building and building materials industries and the nation on the way to health.

THE CHEMISTRY OF MUSCULAR CONTRACTION[1]

by

PROFESSOR E. BALDWIN AND OTHERS

FEW fields of biochemistry have undergone such violent upheavals and few have proved of such value to biochemistry as a whole as that concerned with the biochemistry of muscle. Muscle has been intensely investigated for every one of the forty-odd years since it was given a flying start by the classical experiments of Fletcher and Hopkins. The reason for the intense interest that has been taken in muscle is not far to seek, for it is here rather than in any other tissue that there is the possibility of comparing the amount of work done by a tissue with the amount of chemical change simultaneously taking place.

It now seems tolerably certain that the contraction of a muscle as a whole is, in effect, the resultant of a summation of the molecular contractions of rod- or fibre-like particles of what we used to call 'myosin,' but which we must now recognise as actomyosin, a complex product formed by the interaction of myosin proper with a second muscle protein, actin.

One of the most surprising and at the same time most fundamental discoveries in this exciting field was that of Engelhart and Lubimova who showed, as far back as 1939, that myosin, the principal protein of muscle tissue, is a potent enzyme for the decomposition of adenosine triphosphate (ATP), essentially an exergonic process. Lohmann's experiments had already made it clear that the earliest known energy-yielding reaction taking place in muscle extracts is not the breakdown of glycogen nor yet the decomposition of phosphagen, but that of adenosinetriphosphate itself. Lohmann's work showed too that ATP breakdown is a necessary preliminary to these other metabolic degradations. Engelhart's work provided therefore a striking proof of the intimacy of the relationship between the contractile elements of the muscle cell on the one hand and the most probable chemical energy-source on the other. These two components stand to each other in the relation of an enzyme to its substrate, as close an association as is known to biochemistry.

During recent years a large number of investigators have studied the relationships existing between ATP, ATP'ase (or myosin), actin and actomyosin. Two new contributions to this field of enquiry are to be laid before you this morning. But many problems still remain and there is still much that is open to criticism. It seems to me, therefore, that perhaps I can serve you best by reminding you of some of the principal features which go to make up the *décor* within which the molecular ballet of muscular activity is performed.

In 1907, destroying once and for all the presumed vitalistic omnipotence of 'inogen molecules,' Fletcher and Hopkins showed that the activity of frog muscles kept under anaerobic conditions involves the breakdown of glycogen to lactic acid. If a muscle in which lactic acid has been allowed to accumulate is allowed access to oxygen, a part of the lactic acid undergoes oxidation, the remainder being re-formed into glycogen. These observations, which provided the first sure evidence of an association between muscular activity and glycolysis, ushered in what might be called the 'lactic acid era' of muscle biochemistry. For many years it was pretty universally believed that the energy expended by the active muscle is

[1] Report of a joint discussion in the Sections of Chemistry and Physiology on September 6, 1950, during the Annual Meeting of the British Association.

drawn from the breakdown of muscle glycogen which is, of course, an exergonic process. This, as we know to-day, is true enough. But glycogen breakdown, whether anaerobic by glycolysis or aerobic by oxidation, is not the *immediate* source of contraction energy.

That contraction can take place, aerobically or anaerobically, without glycogen breakdown or formation of lactic acid was first discovered some twenty years later by the pharmacologist, Lundsgaard. The muscles of an intact frog or isolated frog muscles poisoned with iodoacetate will contract normally for some time, but go soon into rigor. No lactic acid is formed and, indeed, the *p*H of the poisoned muscle in rigor is not acid as it is in unpoisoned muscle, but even slightly alkaline. Clearly, then, while glycogen breakdown may well be the *eventual* source of the energy dissipated in muscular activity, it cannot be the *immediate* source.

In 1928, two years before Lundsgaard's work appeared, the presence in muscle of a new compound was demonstrated practically simultaneously by Eggleton and Eggleton in this country and by Fiske and Subbarow in the United States. This new substance, ' phosphagen ' or creatine phosphate, occurs only in vertebrate muscles but, as Meyerhof was the first to show, is replaced in invertebrates generally by arginine phosphate. More recently it was shown by Baldwin and Yudkin that still other ' phosphagens ' exist in at least one invertebrate phylum, but so far as evidence goes all these ' phosphagens ' function in the same manner as does the creatine phosphate of vertebrate muscles.

The activity of iodoacetate-poisoned muscles is attended by the breakdown of phosphagen. With continuing activity phosphagen continues to break down and the muscle goes into rigor as soon as its stock of phosphagen has been exhausted. The decomposition of phosphagen, like glycolysis, is essentially an exergonic process and one which can support muscular activity even when glycolysis is totally arrested ; and we pass, with Lundsgaard's observations, out of the ' lactic acid ' into the ' phosphagen era ' of muscle biochemistry. At this stage of our knowledge the normal, unpoisoned muscle could be superficially likened to an air-gun in which, by pressing the trigger, the stored up energy of phosphagen could be released very rapidly indeed, to be subsequently and rather more slowly replaced by a lever in the form of the glycolytic mechanisms of the muscle cell.

At about this time the use of cell-free muscle extracts, first introduced by Meyerhof, was coming into prominence, and knowledge of the finer and more intimate details of the glycolytic reaction-sequence was growing apace. The addition of phosphagen to such an extract is followed by its rapid breakdown, apparently by hydrolysis, to yield free creatine and free inorganic phosphate :

$$CP \longrightarrow C + P$$

The mechanism of this apparently hydrolytic process was studied by Lohmann who, in 1934, made the key observation that no breakdown of phosphagen takes place if it is added to *dialysed* muscle extracts, suggesting that a dialysable coenzyme of some kind must be involved in the breakdown. This coenzyme Lohmann identified as adenylic acid, or adenosine monophosphate. In the presence of the muscle enzymes the following reaction took place :

$$AMP + 2\ CP \rightleftharpoons ATP + 2\ C$$

Phosphagen breaks down, then, not by hydrolysis but by *the transference of its phosphate radical* to adenosine monophosphate. Later work has made it clear that this is a two-step process ; one enzyme, usually known as the Lohmann enzyme in honour of its discoverer, catalyses a transfer reaction between creatine phosphate and adenosine*di*phosphate :—

$$ADP + CP \rightleftharpoons ATP + C$$

Adenosinediphosphate can arise from the monophosphate through the action of a second enzyme, myokinase :

$$AMP + ATP \rightleftharpoons 2\ ADP$$

Now according to the best analytical data available, muscle normally contains no ADP, though it does contain a powerful enzyme which can produce ADP from the ATP which *is* present. Thus, whatever the mechanism of the Lohmann reaction may be, Lohmann's investigations show

beyond all reasonable doubt that no phosphagen can break down *unless and until some breakdown of ATP has already taken place.* Thus we enter into the 'ATP era.'

With the breakdown of ATP as the earliest known exergonic reaction in muscle extracts and, by strong presumption, in intact muscle cells also, phosphagen fell back into the position of a phosphate + energy store, available for the rapid resynthesis, by way of the Lohmann reaction, of ATP from ADP left after an earlier breakdown of ATP. If there are still earlier reactions in the intact muscle *in situ* we still do not know what they may be. A. V. Hill, in his usual charmingly mischievous manner, has even challenged the biochemists to prove that ATP does indeed break down in muscular contraction, except, that is, in very advanced fatigue or in rigor. As every biochemist knows, moderate exercise is attended by a fall of glycogen, a formation of lactic acid if conditions are anaerobic, and a breakdown of some part of the phosphagen, but there is no observable change in the ATP content of the muscle. The current riposte to Hill's challenge is to point out (a) that no earlier reactions are at present known, (b) that the rephosphorylation of ADP at the expense of phosphagen is an exceedingly rapid process, and (c) that ATP probably does not break down in contraction in any case, but more probably in relaxation, as we shall see presently.

All other processes—breakdown of phosphagen, glycolysis and oxidation, seem uniquely directed towards the synthesis of ATP.

It was shortly after the beginning of the 'ATP era,' I think in 1939, that Engelhart and Lubimova's demonstration broke upon an at first unbelieving world. Their experiments have, however, been repeatedly confirmed and their claim stands fast: myosin is indeed a powerful and specific adenosinetriphosphatase, catalysing the conversion of ATP into ADP, inorganic phosphate and, of course, energy. This energy appears as heat *in vitro*, but—or so we believed—as mechanical work *in vivo*.

The next phase was characterised by an epidemic of experiments designed to demonstrate, if possible, that some shortening of the contractile, rod-like, enzyme molecules of myosin takes place in the presence of the substrate, ATP. Evidence in conformity with this expectation was, indeed, obtained by several groups of workers, and we began to think that the end was already in sight. But more was still to come. Straub's separation of a new protein, actin, from supposedly pure myosin brought our ideas back once more into the melting pot.

Actin, we have now learned, reacts with myosin under closely defined physicochemical conditions rather precisely resembling those which probably obtain inside the intact muscle *in situ*, to form long, fibre-like particles of actomyosin. It is this actomyosin rather than myosin proper which shortens under the influence of ATP but, unlike myosin itself, actomyosin does not catalyse the breakdown of ATP. This phenomenon of shortening is brought about very specifically by ATP and has been demonstrated on the molecular scale, in artificial threads spun from actomyosin sols, in fine bundles of muscle fibres stripped from intact muscles preserved for weeks or months in 50 per cent. glycerol at low temperatures, in isolated muscle fibres, and even in intact muscles *in situ* by close arterial injection of ATP.

It seems probable that when ATP is added to actomyosin it displaces the actin component and unites with the residual myosin, the particles shortening as this takes place; but there is no decomposition of ATP during this phase of activity. The myosin-ATP complex now, apparently, decomposes to regenerate myosin, which again unites with actin to form the longer fibres once more, together with ADP, inorganic phosphate and energy: energy which is used, apparently, *to restore the actomyosin fibre to its extended, or relaxed, configuration.*

Let me remind you at this point that we still do not know how the arrival of a nerve impulse in the muscle initiates the chain of events which culminates in the shortening of the muscle fibre, but I would point out that neither of the known neurohormones, acetylcholine and adrenaline nor any similar or related substance so far tried induces the actomyosin fibres to shorten in the way that ATP does.

Further, since it seems that actomyosin and ATP are normal constituents of resting muscle, and, since if these have access to each other their union results in a process of shortening, it is necessary to suppose that they are kept apart in some way so long as the muscle remains relaxed. How this might happen we do not at present know. Nor do we know precisely how actin reacts with myosin, how ATP acts upon the actomyosin complex, nor in what manner the shortening takes place. There are, you see, still many gaps in our picture.

Let me next say that the picture I am putting before you is but one of the possible interpretations of the experimental facts of the case, but it seems to me to be in best accord with those facts. It seems at the present time that the contractile system of muscle consists of thread-like particles of actomyosin rather than of the shorter and more rod-like particles of myosin itself. Actomyosin does not decompose ATP but reacts with it, shortening in the process. It would appear that the true resting state in muscle is the contracted condition, for it seems that ATP can only begin to decompose *after* the shortening process has taken place. Relaxation rather than contraction is to be thought of as the 'active' or energy-consuming process, for it is in relaxation rather than in contraction that the energy-yielding breakdown of ATP most probably occurs.

Such a theory as this would go far towards explaining what has always struck me, and must I am sure have struck many of you, as one of the most remarkable of all forms of muscular activity. I refer to the ability of the adductor muscles of certain lamellibranch molluscs, such as the scallop, the clam and the oyster, to keep the shells closed for long periods and against relatively enormous forces. What is so remarkable here is that the energy expenditure involved in doing this is practically insignificant. You can find a very able discussion of this problem in Ritchie's *Comparative Physiology of Muscular Tissue*, together with numerous data.

But if it is indeed true that the contracted state is also the resting condition of the muscle we are in a fair way to understanding this phenomenon. But it raises at once a new problem. For if, as there is some reason to think, ATP, in inducing the contractile change, displaces actin from its partnership with myosin so that a myosin-ATP complex is formed, how does it happen that this complex is not promptly broken down with a large-scale release of energy? Is there perhaps some stable, intermediary complex involving all three components, actin, myosin and ATP?

In the main, as is common knowledge, studies of the biochemistry of muscle have been directed solely towards striated muscles. May it not be that these plain, unstriated muscles are differently organised, and may it not also be that we have been in error in neglecting these much less dramatic forms of muscular activity? Perhaps the time has come when, by extending our studies to other than the striated kinds of muscles, new facts might be revealed that could help to resolve the mysteries that still confront us.

Dr. S. V. Perry, in opening his contribution on 'Adenosinetriphosphate and the Isolated Myofibril,' first referred to the normal structure of skeletal muscle. He described how efforts to extract either the sacroplasmic or myofibrillar components of the tissue, although successful, destroyed the normal structure. However, he showed how it was possible to obtain isolated myofibrils from rabbit skeletal muscle by a method using collagenase derived from *Clostridium welchii*. This eliminated the connective tissue, and the myofibrils left were intact, which he demonstrated in an electron microphotograph in which the cross striations characteristic of the whole muscle were clearly seen. Threads of protein, probably actomyosin, running through the length of the myofibril, were also visible. These appeared to be anchored at the 'Z' bands. Shortening of these myofibrils in presence of low concentrations of adenosinetriphosphate ($0 \cdot 0004\ M$) takes place. The fibre in these conditions shrinks to about one-quarter of the relaxed length, and considerable organisation of the myofibrillar structure remains. This also was illustrated by an electron micrograph.

In the presence of repeatedly washed

preparations of myofibrils, adenosinetriphosphate breaks down to adenosinediphosphate, but if the washing is inadequate apparently myokinase may cause the reaction to reach the adenosine monophosphate stage. Muscles in rigor mortis are not structurally disrupted as are frozen and thawed preparations, and decomposition of ATP in rigor mortis is apparently not accompanied by any considerable shortening of actomyosin. This is possibly due to the activity of the recently discovered magnesium activated adenosinetriphosphatase of Meyerhof.

Examination of the adenosinetriphosphatase activities of the washed preparation in presence of magnesium and calcium showed differences compared to the activities of extracted actomyosin under similar conditions. The physical response of isolated myofibrils to adenosinetriphosphate also differed from that of artificial actomyosin threads. The shortening of the latter is basically a synaeresis, and the shrinkage is isodimensional. The response of the myofibrils consisted mainly of a longitudinal shortening, in which respect they more nearly resembled the normal contraction of intact muscle. These differences were ascribed to structural characteristics of the two systems. Dr. Perry concluded with a discussion of the possible relationships of the enzymic and structural organisation of the muscle cell to the contractile activity of the cell.

Dr. J. R. Bendall's paper on ' Shortening of Muscle in Rigor Mortis ' followed. Dr. Bendall made the provisional assumption, with full knowledge of the possible difficulties, that rigor mortis contraction could be regarded as a protracted (and irreversible) type of muscular contraction. Mammalian muscle (*psoas* muscle of rabbit) will always shorten to some extent when going into rigor. The extent of the shortening varies with the temperature of the muscle, the *p*H and the load. At room temperature the shortening is small in extent, but at higher temperatures, particularly when associated with high *p*H, the work done is considerable. Values obtained were of the order of 15 g.cm./g. of muscle against loads of 50–100 g./sq. cm. cross section, at 35° C. and high (e.g. 7·25) *p*H values.

The chemical concomitants of rigor mortis contraction include breakdown of creatine phosphate, breakdown of adenosinetriphosphate and lactic acid formation. These are, of course, also found in normal muscular contraction. By plotting these three phenomena quantitatively against time and degree of shortening, it was seen that no correlation existed between the breakdown of creatine phosphate and the shortening of the muscle *post mortem*. On the other hand the breakdown of adenosinetriphosphate and shortening are well correlated ; shortening never began before the breakdown of adenosinetriphosphate.

This finding implies that, if Dr. Bendall's data can be applied to normally contracting muscle, the shortening phase, rather than that of elongation, is the one associated with breakdown of adenosinetriphosphate.

The constancy of the correlation between the breakdown of adenosinetriphosphate and shortening due to rigor mortis was emphasised by Dr. Bendall ; this obtained in fatigued muscle, in glycogen-depleted muscle, and glycogen-rich muscles and in other conditions.

These observations, Dr. Bendall noted, could account for the thermal data of Professor A. V. Hill, if one accepted the original assumption as to the nature of *rigor mortis* contraction.

PHENOMENA AT LOW TEMPERATURES[1]

by

W. J. T. DUNSTAN

THE numerous properties peculiar to matter at low temperatures have been, for the past fifty years, of considerable interest from the theoretical point of view. Some of these properties we shall consider below: for the present we may mention the specific heats of solids, the data on which provide some of the most important experimental evidence for the quantum theory, and the phenomena of superconductivity and superfluidity, which provide problems still largely unsolved. The radical changes occurring under these extreme conditions throw a new light on many of our fundamental concepts in physics, and it is of interest, and not without importance, to consider how far these concepts would be changed if low temperatures were normally used in experimental work—if 'room temperature' were say three degrees absolute rather than three hundred. We may notice at once that our ideas on hydrodynamics and electromagnetism would be considerably altered: Bernoulli's Theorem is certainly not true for liquid helium, while Maxwell's Equations, if not precisely untrue, become at any rate somewhat uniformative identities. Specific heat, again, becomes a rather artificial concept under these conditions; its practical value lies in the fact that in normal circumstances it is nearly constant over a fairly wide range of temperature. This is by no means true in the low temperature field, where the total thermal energy (the internal energy of thermodynamics) is a more natural quantity to employ; specific heat is merely its rate of change with temperature.

It is also worth while to examine the position of temperature itself under these conditions. Considerable attention has been given to the meaning of temperature in recent years, and the subject is frequently given a law of thermodynamics to itself (the 'zeroeth law'). A definition of temperature still sometimes met, as determining the direction of flow of heat between two bodies, is now recognised as unsound, since one does not in fact observe the heat flow but only the temperature changes accompanying it. This definition does, however, indicate one important property of temperature, namely its tendency to reach a uniform value throughout an isolated system. It has been questioned whether this equalisation does always occur at the very low temperatures produced by adiabatic demagnetisation, at any rate in any reasonable period of time. It will be convenient to consider this method here, in order to understand the point raised.

The object of the method is to extract some of the potential energy of the magnetic dipoles of paramagnetic salts. When these substances are placed in a magnetic field, work is done by the field in aligning the dipoles parallel to itself, and heat is generated. Heat will therefore be absorbed when the field is removed, and, if the substance is thermally isolated, the temperature must fall. Temperatures estimated at 0·0034° K. have been produced this way.

In the arrangement due to Kürti and Simon (1), the specimen is first cooled to the temperature of liquid helium, contact with the container of this liquid being made by helium vapour at low pressure, and the field, produced by an electromagnet, is applied. The heat generated is conveyed to the liquid. The vapour is now pumped away, and the field removed; the rapid fall of temperature of the specimen produces condensation of the helium vapour, greatly aiding the work of the pump, which may in some cases be dispensed with altogether. In fact, the vacuum produced in this way is the most perfect obtainable: at 0·1° K, the vapour

[1] 'Endeavour' Prize Essay, 1950.

pressure of helium is of the order of 10^{-33} mm. of mercury. This also makes the thermal insulation extremely good; gain of heat occurs principally through condensation on the specimen of helium adsorbed on the walls of the container, and, according to Hull and Cooke (2), may be kept down to one erg per minute.

The temperatures obtained are measured by determining the magnetic susceptibility of the specimen, and applying Curie's law, that the susceptibility varies inversely as the temperature. This 'magnetic thermometer' thus measures the temperature associated with the distribution of energy among the molecular dipoles. The work of Heitler and Teller (3) suggests that interchange of energy between the dipoles and the vibrations of the ionic lattice may be so slow that two temperatures, the dipole or 'spin' temperature, and the temperature associated with the lattice vibrations, may exist simultaneously in a solid, even over a period of weeks. Experiments, notably those of Allen and Shire (4), who compared the readings of a magnetic thermometer with those of a phosphor-bronze resistance instrument, which, depending on collisions between electrons and the lattice, presumably measures the temperature of the latter, have not confirmed this prediction, so that, experimentally, the position is satisfactory. The theoretical point, however, remains, and apparently the time lag must become appreciable at sufficiently low temperatures.

Again, the definition of equality of temperature given in the 'zeroeth law' (which states essentially that if any thermometer gives the same reading when in contact with each of two bodies, it will read the same after they are brought into contact, in the absence of chemical reaction) assumes that a thermometer can in fact measure the temperature of a body. But the work of Heitler and Teller attacks just this assumption in the case of the paramagnetic salts.

Thus far we have been concerned with a case where equilibrium, though possibly it can be long delayed, will finally occur. We must now describe some phenomena, those of superfluidity and superconductivity, which suggest the permanent existence in one fluid, of two sets of particles, of considerably different energies, the particles of one set behaving as if they were at zero temperature, while the temperature of the other set remains finite.

Liquid helium was first obtained by Kamerlingh Onnes in 1908, and during the following years the physical properties of the liquid were investigated extensively at Leiden. It was found that many of these properties varied with temperature in a somewhat unusual way in the region of 2·19° K.; in particular, the specific heat exhibits a lambda-point with its maximum at this temperature, where the density also has its greatest value. Liquid helium I and Liquid helium II are the names given to the substance above and below the lambda-point respectively.

A phenomenon of this type is common enough in solids, where it is normally associated with some change in the order of the arrangement of the molecules, or of the orientation of their rotations, but is somewhat unexpected in a liquid. More remarkable, however, are the effects examined by Daunt and Mendelssohn, Allen, Reekie, Kapitza, and others. Their results may be summarised as follows: when any solid body is partially immersed in liquid helium II, a film of the latter creeps up the unimmersed portion of the solid; thus, if a beaker is lowered into the liquid, the film creeps over the top of the beaker, in which helium collects until the levels inside and out are the same. The rate of transport is found to be proportional to the perimeter of the solid (thus excluding explanations based on distillation), to be independent of the nature of the latter, and also, in the case of the beaker, to be nearly independent of the pressure difference. The same phenomenon is observed with narrow tubes, through which there is a transport of helium by this creeping film, as well as that due to hydrostatic pressure. This results in discordant values of the viscosity, according to whether this is determined by the capillary tube method, or by say the rotating cylinder method. In the former case, Poiseuille's formula is found not to apply, but if this formula is used to calculate a value for the viscosity, results as low as 10^{-9} c.g.s. units may be obtained. Again, if two beakers of the liquid are connected by a narrow tube, or if contact is made by the creeping film

alone, and heat is supplied to one beaker, helium flows into this vessel until a considerable head of pressure is set up. A remarkable demonstration of this effect is obtained by using a horizontal tube filled with emery powder, producing many fine channels, connected at one end to a vertical jet, which projects out of the liquid surface. If heat is supplied at this end by radiation from a small lamp, the rush of fluid through the channels in the emery powder forces liquid out of the jet to a height of as much as 30 cms. (the fountain, or thermomechanical, effect). Conversely, if the liquid is forced through a narrow opening, the temperature is found to fall. This state of affairs naturally complicates thermal conductivity in the substance, mass motion being superimposed on the ordinary processes of heat transfer, and if the conductivity be calculated by Fourier's Equation, which however does not hold, results of as much as 2,000 cals. cm.$^{-1}$ deg.$^{-1}$ sec.$^{-1}$ are obtained. Heat in fact is transferred in the absence of a temperature gradient, and if the transport is entirely through the film, the process is apparently strictly isothermal. It may be remarked finally that these phenomena appear at the lambda-point, and seem to tend to disappear as the temperature falls below 1° K.

Superconductivity was another discovery of the Leiden physicists. It occurs in a number of metals and alloys, and its salient feature is that below a certain temperature (the transition temperature), the electrical resistivity disappears. By setting up currents in two closed superconducting rings, one fixed, the other suspended from a torsion fibre in the plane of the fixed ring, and showing that the twist in the suspension due to the repulsion between the two currents remained constant over long periods of time, Tuyn (12) was able to show that the resistivity was certainly less than 10^{-17} ohm-cm. Superconductivity is destroyed by a sufficiently large current density in the specimen, or by a magnetic field greater than a critical, or threshold, value : the former effect is thought to be a special case of the latter. The Thomson and Peltier co-efficients of a superconductor and of a junction between two superconductors respectively, are zero. The onset of the phenomenon is accompanied by a specific heat anomaly similar in general form to a lambda-point ; destruction of superconductivity by a magnetic field, however, is an ordinary phase-transition.

The effect of a magnetic field on the resistance suggested enquiries as to the magnetic properties of a superconductor, and these led to the remarkable result that the magnetic induction in such bodies is zero, so that the volume susceptibility is $-\frac{1}{4\pi}$ (the Meissner Effect). This introduces complications in the investigation of threshold fields, since, for any specimens but long cylinders placed parallel to the field, the distortions of the latter introduced by the conductor itself cause the critical value to be reached at some points before others, producing a complex intermediate state in which the specimen contains both normal and superconducting portions.

Substitution of the conditions of infinite conductivity and zero permeability into Maxwell's Equations yields the result that the current density must be zero, so that the current is confined to a thin surface layer. A modified form of the equations, due to F. and H. London, gives a value of the order of 10^{-5} to 10^{-6} cms. for the depth of the layer ; there is some experimental support for this.

We can now take up the theoretical discussion of these effects along the lines indicated above ; we shall consider first liquid helium II, which is to be regarded, on this theory, as consisting of a mixture of atoms in the two lowest energy levels, the fraction in the lowest level varying from 1 at the absolute zero to 0 at the lambda-point ; the difference in energy between the two levels is postulated to be considerable. The atoms in the lowest level, or superfluid atoms, cannot lose energy, nor therefore momentum. The momentum they possess makes them spread, or diffuse, over surfaces, thus accounting for the creeping film and the analogous flow through narrow tubes, where the surface area is large compared with the volume. Some of these atoms will be able to take up energy from the surface, becoming normal atoms, but the energy available for this is small, owing to the large gap between the energy levels. If, however, heat is supplied at any point, there will be a rapid

conversion of superfluid into normal atoms there, and hence more superfluid atoms will diffuse towards this point—the fountain effect and the allied phenomena. The superfluid atoms, or *z*-particles as Mendelssohn (5) names them in his more general discussion, behave exactly as they would at the absolute zero ; they have a constant energy, and, according to Nernst's Heat Theorem, zero entropy. This result is supported by experiments in which the liquid is forced through narrow apertures : the temperature and entropy of unit mass fall, but the total entropy of the liquid on either side of the aperture remains constant, showing that the helium atoms passing through (via the creeping film) convey no entropy. The *z*-particles cannot react with the normal particles, but are greatly affected by external sources of energy.

Superconductivity is similarly regarded as a frictionless diffusion of electrons, which cannot exchange energy with the lattice. The specific heat of these electrons should be zero : the vanishing of the Thomson co-efficient indicates that this is so.

This explanation, so far as it goes, is satisfactory and attractive. It must be emphasised, however, that we have at the moment no theoretical basis for the assumption made as to the available levels, far less any numerical values for these.

It will be seen that, if this theory is correct, liquid helium II might be described as a mixture of atoms at 0° K., and of atoms at the lambda-point. It is not suggested that this description is necessarily satisfactory, but it does indicate that temperature ceases to be such a simple concept as it appears to be under normal conditions.

To try to understand these difficulties, we may examine the subject from the statistical point of view, for although our first knowledge of temperature is obtained from physiological sensation, much of the utility of this quantity, and in particular of the absolute scale, which alone possesses a theoretical foundation, is associated with the applicability of classical statistics, and above all of the Theorem of the Equipartition of Energy, to most phenomena at room temperature. Associated with the equipartition theorem is the idea of the perfect gas, to which real gases approximate, in which the product of pressure and volume is proportional to the absolute temperature, and the specific heat is constant. This accounts for the importance, early recognised, of the gas thermometer, the use of which, however, becomes impossible at the lowest temperatures. Of almost as great practical importance is what we may call the ' perfect solid,' composed of atoms undergoing strictly harmonic oscillations, and thus obeying Dulong and Petit's Law, and having constant specific heat ; in accordance with Grüneisen's Law, such a solid also has a constant expansion coefficient. Thermometers based on expansion, therefore, do at least approximate to the absolute scale.

At low temperatures, the position is different. Deviations from classical statistics become appreciable ; the equipartition theorem, with its corollary that the energy associated with each degree of freedom is proportional to the absolute temperature, no longer holds. The mean energy of an oscillator of frequency n is given by the expression

$$\frac{hn}{e^{\frac{hn}{kT}} - 1}$$

(h Planck's constant, k Boltzmann's constant), in which the temperature T occupies a less predominant position. It is more convenient, indeed, to employ as Fowler has done, a ' statistical temperature ' θ, defined by

$$\theta = e^{-\frac{1}{kT}}$$

Since temperature appears to be less significant in the equations appropriate to the low temperature field, should we abandon it as a fundamental quantity, and take, as many theoretical physicists have done, energy and entropy as our starting points ? Temperature is then defined as the reciprocal of the derivative of the entropy with respect to the internal energy, when the system does no external work :

$$\frac{1}{T} = \left(\frac{\partial S}{\partial U}\right)_x$$

(x being a generalised displacement). It may be remarked that the instruments commonly used for measuring the lowest

temperatures, the helium vapour pressure thermometer and the magnetic thermometer, do in fact allow the temperature to be calculated only by appeal to the properties of entropy. Temperature is calculated with the vapour pressure thermometer by the formula of Bleaney and Simon (6), which is obtained by thermodynamical considerations, and involves the statistical mechanical expression for the entropy of a gas. With the magnetic thermometer, the observed temperature T* is reduced to the absolute scale effectively by using the equation given above : we put

$$T = \frac{dQ}{dS} = \frac{\left(\frac{\partial Q}{\partial T^*}\right)_{H=0}}{\left(\frac{\partial S}{\partial T^*}\right)_{H=0}}$$

$\frac{\partial Q}{\partial T^*}$ is the thermal capacity of the T* scale, and is measured experimentally ; $\frac{\partial S}{\partial T^*}$ is determined by calculating $\left(\frac{\partial S}{\partial H}\right)_{T^*}$ and finding $\left(\frac{\partial H}{\partial T^*}\right)_S$ by the adiabatic demagnetisation experiments. We see then that it is difficult to treat temperature without consideration of entropy.

In the previous discussion, we have perhaps minimised the importance and utility of temperature. In fact, temperature must remain a fundamental quantity ; we have endeavoured to show, however, that at low temperatures (and the very use of this phrase shows that we cannot abandon the concept), it is difficult to define temperature as other than a parameter determining the distribution of the elementary systems of an assembly among the available energy levels. Also, we find that entropy, which appears so artificial a quantity when first met, is likewise of fundamental importance ; its properties seem to become more apparent as the absolute zero is approached.

It would be incorrect to conclude this account without some reference to the experimental techniques of Low Temperature Physics, especially in view of the number of noted physicists who have exercised their ingenuity in this field : one may mention in particular Wroblewski and Olszewski, who at Cracow carried out many experiments, even at temperatures approaching that of liquid hydrogen, before the invention of the Dewar flask, and, more recently, Simon and Kapitza, with their small-scale arrangements for producing low temperatures and liquefied gases.

Temperatures down to 1° K. are obtained by the use of baths (cryostats) of various substances gaseous under normal conditions, and in fact low temperatures may conveniently be classified as liquid air (approximately 90° to 55° K.), liquid hydrogen (20° to 14° K.) and liquid helium (4° to 1° K.) temperatures, according to the liquid used in the cryostat. The liquid, contained in a Dewar vessel, which in the case of hydrogen and helium is surrounded by a second flask containing a substance of somewhat higher boiling point, is kept well stirred, and its vapour pressure is held constant by connecting the enclosed space above it to a needle valve and vacuum pump. The advantage of using liquids in this way is twofold : the temperature may be kept uniform by stirring, which is impossible with solids, and further, the temperature of a liquid in contact with its vapour alone is completely determined by the pressure, which may be adjusted by the pump. For many purposes, indeed, the vapour pressure gives a sufficient and convenient indication of the temperature. The gaps in the ranges given above for the various cryostats are somewhat difficult to bridge : frequently the apparatus is kept at constant temperature by a stream of gas first cooled by passing through a liquid bath, the final adjustment being made most elegantly by Joule-Thomson cooling at a nozzle, an arrangement used by E. H. and Ezer Griffiths (7), and by Ruhemann (8). Solid hydrogen, a relatively good conductor of heat, may also be used in a cryostat.

The liquefaction of the gases may be effected in two ways : as Lindemann (9) has pointed out, we may remove energy from the gas molecules either by causing them to do work against intermolecular forces by allowing the gas to expand at a throttle, or by making them rebound off a surface moving away from them, when their kinetic energy is diminished. To

show this, let u and v be the velocities of a molecule before and after collision (assumed perfectly elastic) with a surface moving with velocity V (in the same sense as u). Then

$$u - V = -(v - V),$$
$$\text{i.e.} \quad v = -u + 2V$$

and so v is numerically less than u. We neglect the change in V, since the mass of the moving surface will be large compared with the mass of the molecules.

These two methods are both in use : the former, the internal work method, is the basis of the Linde liquefiers ; owing to the small magnitude of the forces between the neutral gas molecules, it is theoretically the less efficient process, a defect largely counteracted in practice by increased simplicity, and in particular by the absence of moving parts, compared with the second, or external work, method, used commercially in the Claude and Heylandt processes. The efficiency of the second process, as is seen, will be increased by raising the velocity of the moving surface ; Kapitza has taken advantage of this by using a turbine in place of the usual cylinder and piston, giving an efficiency comparable with that of other methods, while using much lower input pressures.

The external method has also been used by Simon to produce liquid helium. Helium gas is compressed to about 150 atmospheres, and cooled by liquid hydrogen ; then, after removing the latter, the pressure is released. The method, similar to that originally used by Cailletet for liquefying air, is in this case highly efficient because of the very small thermal capacity of the container at these temperatures, and because the excellent thermal insulation enables the expansion to be carried out slowly, and therefore with greater thermodynamic efficiency. Apparatus may, if desired, be immersed previously in the helium, and experiments carried out with this arrangement, which is a notable example of the practical utilisation of the properties of matter at low temperatures.

There is a very interesting class of experiments in which low temperatures are used in place of some other extreme condition, such as high pressures, as in Simon's work on phase equilibrium (10). Simon pointed out that, in investigating solid-liquid equilibrium, and particularly in searching for a possible critical point for transition between these phases, we must first inquire what is meant by a high pressure in this connection ; he further suggested that the ratio of the applied pressure to the triple-point pressure was more significant from this point of view than the value of the pressure itself. He therefore carried out experiments with neon, hydrogen, and helium, which, indeed, shows no triple-point : the solid-liquid and liquid-vapour curves do not intersect. Pressures up to 5,600 atmospheres, when the solid melts at 40° K., some eight times the critical temperature, were used ; no indication of a continuous transition from solid to fluid was obtained. This work is a valuable supplement to that of Bridgmann, which was carried out with more normal temperatures, and extremely high pressures. We may also mention the use, by Onnes and Woltjer (11) of low temperatures instead of strong magnetic fields in producing paramagnetic saturation.

We have endeavoured to give some description of phenomena at low temperatures, paying particular attention to those properties which seem of importance as providing new points of view on our fundamental ideas in physics, and to experimental work in which advantage has been taken of specificially low temperature phenomena to extend our knowledge of Nature : investigations of this kind, on account both of their power and their charm, are surely indicative of the work of great physicists.

References

(1) Kurti and Simon, *Proc. Roy. Soc. A*, **149** (1935), p. 152.
(2) Hull and Cooke, *Proc. Roy. Soc. A*, **181** (1942), p. 83.
(3) Heitler and Teller, *Proc. Roy. Soc. A*, **155** (1936), p. 629.
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(5) Mendelssohn, *Proc. Phys. Soc.*, **57** (1945), p. 371.
(6) Bleaney and Simon, *Trans. Faraday Soc.*, **35** (1939), p. 1205.
(7) E. H. and Ezer Griffiths, *Proc. Roy. Soc. A*, **89** (1914), p. 561.
(8) Ruhemann, *Zeit. f. Physik*, **65** (1930), p. 67.
(9) Lindemann, *Nature*, **135** (1935), p. 693.
(10) Simon, *Zeit. Physik. Chem. B.*, **6** (1929), p. 62.
(11) Onnes and Woltjer, *Leiden Commun.*, 167c.
(12) Tuyn, *Leiden Commun.*, 198.

SEISMOLOGICAL INVESTIGATIONS

FIFTY-FIFTH REPORT of COMMITTEE on Seismological Investigations (Dr. R. STONELEY, F.R.S., *Chairman*; Lt.-Col. E. TILLOTSON, *Secretary*; Mr. E. F. BAXTER, Miss E. F. BELLAMY, Prof. P. G. H. BOSWELL, O.B.E., F.R.S., Mr. B. C. BROWNE, Dr. E. C. BULLARD, F.R.S., Dr. G. E. R. DEACON, F.R.S., Dr. A. T. J. DOLLAR, Dr. A. E. M. GEDDES, O.B.E., Prof. G. R. GOLDSBROUGH, C.B.E., F.R.S., Dr. WILFRED HALL, Mr. M. N. HILL, Dr. O. J. R. HOWARTH, O.B.E., Mr. J. S. HUGHES, Prof. H. JEFFREYS, F.R.S., Mr. COSMO JOHNS, Mr. E. N. LAWRENCE, Dr. A. W. LEE, Prof. J. PROUDMAN, F.R.S., Dr. A. O. RANKINE, O.B.E., F.R.S., Rev. C. REY, S.J., Dr. G. D. ROBINSON, Dr. F. J. SCRASE, Mr. H. V. SHAW, Sir FRANK SMITH, G.B.E., K.C.B., Dr. J. M. STAGG, and Dr. P. L. WILLMORE.)

Personal.—The Committee deeply regret the death on May 4, 1950, at the age of 58, of Dr. H. Shaw, Director of the Science Museum, South Kensington, and a member of this Committee since 1930. In addition to his own work on geophysical surveys, Dr. Herman Shaw was responsible through the Science Museum for making accessible to the public the knowledge of the working of seismographs and the information they have yielded of the internal constitution of the Earth. He regularly attended meetings of this Committee, and was always willing to give help and advice when needed. Our sympathies go out to Mrs. Shaw in her sad loss.

The Committee welcomes the reappointment of Dr. Bullard on his return to this country.

MEETING OF COMMITTEE.—The Committee met on Thursday, September 1, 1949, at 11.30 A.M. in room 218, Main Buildings, King's College, Newcastle-upon-Tyne.

The Report of the Committee was discussed and approved.

There was a full and general discussion of the means by which an improvement in the recording of earthquakes could be effected in the British Isles.

THE GRAY-MILNE FUND

As mentioned in last year's Report, the sum of £400 has been temporarily invested in 2½ per cent. Defence Bonds and in the year ended June 30, 1950, interest amounting to £6 17*s.* 3*d.* has been received from these Bonds. The Edinburgh seismograms have been read regularly by Lt.-Col. Tillotson, and the relatively small cost of duplicating and circulating the data to a number of seismological observatories has been borne by the Gray-Milne Fund. The balance of the account has increased by over £80 during the period under review.

Gray-Milne Fund

Receipts	£	*s.*	*d.*
Balance, July 1, 1949	517	15	11
Trust Income	80	14	10
Interest on Defence Bonds	6	17	3
	£605	8	0

Payments	£	*s.*	*d.*
Insurance on Seismographs	1	0	0
Duplicating and posting Edinburgh readings	5	18	0
Defence Bonds	400	0	0
(*Temporary Investment*) Balance at Bank	198	10	0
	£605	8	0

INSTRUMENTS

The instruments belonging to the Committee are located, as before, as follows :—

Milne-Shaw Seismographs,	
No. 1	Downe, Kent.
,, 3	Edinburgh.
,, 4	Downe, Kent.
,, 6	Cape Town.
,, 27	Perth, W.A.
,, 63	Suva, Fiji.
Seconds Regulator Clock	Suva, Fiji.
Jagger Shock Recorder	Comrie.

The seismographs at Down House, Downe, Kent, remain in storage. Seismological Reports for Suva, Fiji, from July, 1943, to the end of 1947 have been distributed in mimeographed form by the Dominion Observatory, Wellington, W. I., New Zealand, separately. From the beginning of 1948 to date the readings are included with those of the New Zealand stations in the normal monthly preliminary seismological bulletins from Wellington. The work is thus up to date and continuing.

Review of Scottish Earthquakes, 1916–1949

By Dr. A. T. J. Dollar

Information gathered through the British Earthquake Inquiry, and otherwise, shows that during the third of a century between January 1, 1916 and April 30, 1949, there is evidence for at least 120 tectonic earthquakes in Scotland, including nine principal earthquakes with associated accessory shocks and five others of secondary or sympathetic origin, but no unequivocal evidence for twin earthquakes.

The positions of epicentres indicate nine seismic regions, mainly grouped round the margins of the Grampian Highlands. Of these regions, Glen More, Breadalbane, Ochil Hills and South Argyll show seismic activities noticeably greater than those in the remaining four regions of Clydesdale, Pentland Hills, Lowther Hills and the Shetland Islands.

Among seismic centres, Comrie remains outstanding with 15 earthquakes for the period, followed by Stirling with 11 earthquakes, and Menstrie, Lochgilphead and Lochaber each with 6 earthquakes, for example.

Regarding the temporal distribution of these disturbances, 1940, with 20 earthquakes (16·6 per cent. of the total), was the year of greatest activity, followed by 1927 with 17 earthquakes, 1934 with 16 earthquakes and 1926 with 11 earthquakes, among the remainder. The maximum-epochs of the distribution by months are in January and July, while corresponding maximum-epochs for the distribution by days of the week fall on Saturdays and Sundays. However, these last may reflect more favourable observational conditions at week-ends rather than any real increases in numbers of earthquakes at these times. The chief maximum-epochs for the distribution by hours occurs between 1h. and 2h. G.M.T., and to a less extent between 15h. and 16h. G.M.T. : four other maxima of lesser amplitude also appear.

In connection with durations of these disturbances, available values suggest the average is slightly more than three seconds.

On the Davison Scale, the maximum intensity involved is VII (for an earthquake in Lochaber on December 25, 1946), while the minimum intensity is indistinguishable from that of an earthsound, and the mean value is about IV.

The greatest and least areas of disturbance are approximately 32,000 square miles (for an earthquake at Inverness on August 16, 1934) and 260 square miles (for an earthquake in Central Stirlingshire on July 16, 1940) respectively. The mean area is nearly 8,800 square miles.

Throughout the period involved, the main relief of stress has taken place along faults of N.E.-S.W. trend, but between 1930 and 1938 there was additional activity along some faults of N.W.-S.E. trend.

In nearly two-thirds of the earthquakes concerned, primary earth-sounds have been noticed. Most commonly, these are compared to those made by the passage of a loaded vehicle, the dragging of heavy furniture across a floor, or thunder. The several instances of secondary earth-sounds include those due to movements of house-fittings, furniture or domestic utensils, or to the cries of excited wild or tame birds and animals.

Damage produced by these earthquakes has been slight and almost entirely structural, generally involving no more than dislodgement of tiles, slates or chimney-pots. In one case, the overthrow of a gable-end near Carron Bridge may have be occasioned by earth tremors at Stirling on July 16, 1940. No human injuries seem to have been caused, either directly or indirectly, by any of the disturbances.

An example of an unusual effect due to one of these earthquakes is the momentary alteration in the musical note emitted by

an operating dynamo at Fort William, produced by tremors originating in the adjoining district of Lochaber on Christmas Day, 1946.

International Seismological Summary

By J. S. Hughes, M.A.

There is no change in the production of the International Seismological Summary to be reported this year. Although the first quarter for 1939 is in the press there is some delay in issuing the last quarterly number for 1938, owing to the excessive amount of material dealt with. On November 5 a very large and widely recorded earthquake occurred near Hukusima. This shock, although shallow, was recorded at nearly every station in the world and was followed by many aftershocks from nearly the same epicentre. This involved an unprecedented quantity of observational material which it was necessary to work up. For the purpose of the Summary, and to make the amount of computing a minimum, most of these aftershocks are referred to the mean position 37°·1 N. 141°·8 E. The separate detailed determination of each shock is avoided, but seeing the whole work through the press takes much time.

The lay-out for the 1939 volume will be as for 1938 : the use of Geocentric Direction Cosines is now the accepted practice, and the column for a third reading is a permanent feature.

To date the manuscript for July, 1939, has been prepared, and the copying of 1940 readings is nearly complete.

Experimental Seismology

It is pleasing to note the increased interest in experimental seismology in our universities and research establishments, in addition to the routine investigations made by oil companies.

The following reports have been received :—

Admiralty Research Laboratory.—The results of Admiralty research on microseisms are appearing in two papers, ' The Generation of Microseisms ' by M. S. Longuet-Higgins in the *Phil. Trans. Roy. Soc.* and ' Identification of Microseismic Activity with Sea Waves ' by J. Darbyshire in the *Proc. Roy. Soc.* Efforts to produce a semi-portable microseismograph are continuing.

Imperial College of Science and Technology.—The elastic properties of rocks at frequencies between 40 and 120 cycles per second have been investigated with a view to obtaining data on dispersion and absorption. In addition, experiments have been made in the propagation of elastic waves of frequency between 500 and 1,000 cycles.

University of Leeds, Department of Mining.—The researches of this Department have been concentrated on the ground amplitudes and ' frequencies ' resulting from blasting operations. More precisely the amplitude investigations have been on the relation between charge and amplitude in routine quarry blasting, readings being concentrated in the range of 0–200 lbs. Recordings were made on a Leet 3-component mechanical optical seismograph, using a fixed position for the seismograph and recording blasts of different magnitudes at approximately equal distances from the recording point.

The results obtained indicate that in practical blasting a pure charge-amplitude squared law is not operative but may be applied in modified form if it be assumed that an energy loss is introduced, the proportion of which in relation to the total charge decreases as the charge increases. Further, a considerable spread of amplitude values occurs in such blasting in addition to the usual allowance which must be made for varying overburden conditions.

The Leet instrument is also being used in conjunction with an 8-channel geophone spread to give a direct reading of the ground ' frequencies.' An investigation of Ricker's theory of seismogram structure is being carried out and work has been done at Church Fenton and Grassington, using limestone in each case as a marker bed.

Seismological Work of the Department of Geodesy and Geophysics, Cambridge

Experimental. Experiments were carried out during August, 1949, by Messrs. M. N. Hill and J. C. Swallow to see

whether the method of refraction shooting at sea (see last year's Report) was suitable for deep water. Facilities were provided by the Air Ministry for this work to be undertaken in the *Weather Explorer*, an Ocean Weather Ship, on a routine voyage, and the investigations were carried out in an area of the Atlantic in the neighbourhood of lat. 53° 50′ N ; long. 18° 40′ W. in water of depth about 1,300 fathoms.

Depth-charges, set to fire at 900 feet deep, were used as sources of the seismic waves. These waves were detected by quartz hydrophones suspended approximately 150 ft. below sono-radio buoys which transmitted the information to the recording instruments in the ship. The charges were fired at distances up to twenty miles from the buoys, four of which were in use simultaneously spread over a line approximately three miles long.

Preliminary calculation of results from these experiments showed the presence of two interfaces below the sea-bed layer at depths of 9,200 ft. and 18,000 ft. In the surface layer of the bottom three determinations of the velocity of the compressional waves, at different places within the area, showed that it increased from about 5,000 ft./sec. at the surface of the sea bed to a maximum value of approximately 8,000 ft./sec. The intermediate layer gave velocities of 16,300 and 17,300 ft./sec., while the third type of rock, which extended to an indeterminate depth, gave velocities of 21,700 and 20,600 ft./sec. in two different positions.

If the highly speculative assumptions are made that there are some 9,000 ft. of oceanic sediments, and that Kuenen's value of the rate of sedimentation (reduced to a pore-free basis) is applicable, then the time of deposition would be of the order of 2,000 million years.

A more detailed note on this work was published in *Nature*, February 4, 1950, p. 193.

Dr. Willmore has been further developing the seismographs referred to in last year's Report. Their original object was for recording such phenomena as ' rock-bursts ' over distances of a few hundred km. For field work the seismometer should be robust, easy to assemble and handle, highly sensitive and of relatively short period. The recorder should be capable of resolving time intervals of less than $\frac{1}{10}$ sec. The instruments constructed to meet these requirements have proved their ability to equal or surpass the performance of standard observatory types, whilst their robustness and simplicity are an advantage even under observatory conditions.

The seismometers are of the moving coil type, and can be used either horizontally or vertically. Instruments have been constructed of natural periods 1 sec. and $\frac{1}{3}$ sec., and fit into water-tight cases so that in the field they can be buried in open ground. Each instrument weighs about 20 lb. The seismometers drive mirror galvanometers of period about $\frac{1}{20}$ sec. and the resistances are adjusted so that all moving parts are electromagnetically damped. When the galvanometer is used with a 1 metre light-beam the magnification is about 300,000 at 10 cycles/sec. The drive of the recording drum is by synchronous motor, either from A.C. mains or from a battery and tuning fork. The recorder normally operates in full daylight ; the drum is enclosed in a casette which lifts easily out of the box and can be carried into a dark-room for loading and unloading.

Mr. C. D. V. Wilson has continued his investigation of microseisms in the frequency range 8–120 cycles/sec. Recordings have been made at various sites in and around Cambridge, and also on the Gog Magog Hills. In these places the major effect is due to man-made disturbances such as traffic, and there is accordingly a well marked diurnal variation. Corresponding investigations carried out on Dartmoor and Salisbury Plain, on the other hand, showed no significant differences between night and day.

Dr. Cooper and Mr. Longuet-Higgins have made experiments to confirm the theory that microseisms originate from standing waves on the surface of the ocean.

Mr. J. Hospers, who is on a geological expedition to Iceland, during which he is making some geophysical measurements, has taken with him a short period seismograph to try to discover whether there is any local earthquake activity.

THEORETICAL.—Professors Gutenberg and Richter have adduced strong evidence

that below the surface layers of the continents there is a region in which the velocities of compressional (and presumably distortional) waves are less than in the medium above. The effect of this low-velocity layer on the propagation of surface waves has been discussed by Dr. Stoneley who finds that the effect on the amplitudes will be inadequate to allow the detection of the low-velocity layer by observing the amplitudes of surface waves.

Mr. Longuet-Higgins has continued his work on the connexion between microseisms and sea-waves.

Reappointment

The Committee asks for reappointment without a grant.

BIRMINGHAM MEETING
SECTIONAL TRANSACTIONS

Any references to publication which are supplied by authors will be given in *The Advancement of Science*, No. 28, March, 1951.

SECTION A
Mathematics and Physics
August 31

High energy particles and machines for their acceleration.

Prof. R. E. Peierls, F.R.S.—*Problems in the study of high energy particles.*

Mr. D. W. Fry.—*The linear electron accelerator.*

Dr. L. U. Hibbard.—*The Birmingham proton synchrotron.*

Dr. T. G. Pickavance.—*Experiments with the 110-inch Harwell cyclotron.*

Mr. F. K. Goward.—*Study of photodisintegrations produced in photographic plates by a synchrotron.*

Prof. P. M. S. Blackett, F.R.S.—*Very heavy unstable mesons.*

September 1

Presentation of technical information. (See Section G.).

Civil applications of atomic energy.

Sir John D. Cockcroft, C.B.E., F.R.S.—*The problems and prospects for nuclear power development.*

Dr. H. Seligman.—*Industrial uses for radioactive isotopes.*

Mr. W. S. Eastwood.—*The use of pile-made isotopes for industrial gamma radiography.*

The application of atomic piles to experiments in nuclear physics.

Dr. R. E. Bell.—*Some experiments with the Chalk River pile.*

Mr. T. M. Fry.—*Effects of radiations on solids.*

Mr. G. E. Bacon.—*Neutron diffraction.*

Dr. D. R. Inglis.—*Neutron spectroscopy.*

September 4

Mathematical notation, Presidential Address by Prof. E. H. Neville.

Heat flow in the earth's crust.

Prof. H. Jeffreys, F.R.S.—*The earth's thermal state.*

Dr. S. K. Runcorn.—*The geomagnetic secular change and thermal convection in the earth's core.*

September 5

The lighting of galleries and museums.

Mr. F. I. G. Rawlins.—*The lighting of picture galleries.*

Mr. W. E. Rawson-Bottom.—*Museum lighting.*

Mr. E. S. Calvert.—*Visual aids for landing in bad visibility with particular reference to the transition from instrument to visual flight.*

September 6

Dating the past. (Jointly with Section H).

Mr. J. V. P. Long.—*Dating time by C^{14}.*

Prof. F. E. Zeuner.—*Archaeological and geological aspects of the C^{14} method.*

SUB-SECTION A*
Mathematics
September 4

Dr. J. L. B. Cooper.—*The Heaviside operational calculus.*

September 5

Dr. B. Kuttner.—*Some problems arising in connection with football pools.*

Dr. M. Johnson.—*The meanings of time and space in philosophies of science.*

SECTION B

Chemistry

August 31

Modern developments in carbohydrate chemistry, Presidential Address by Prof. E. L. Hirst, F.R.S.

Dr. E. G. V. Percival.—*Seaweed polysaccharides.*

Prof. S. Peat, F.R.S.—*The enzymes associated with starch metabolism.*

Prof. M. Stacey, F.R.S.—*The chemistry of the bacterial polysaccharides.*

September 1

Chemistry of the cell with special reference to the nucleus (See Section K).

The chemistry of plastics, rubber and fibres.

Prof. H. W. Melville, F.R.S.—*The degradation of high polymers.*

Dr. F. Happey.—*Physico-chemical methods in the study of fibre formation from synthetic polymers.*

Mr. A. E. T. Neale.—*Natural and synthetic rubbers—a comparison.*

Mr. G. Dring and Dr. R. F. Hunter.—*Structural characteristics which determine plastics, rubber and fibres.*

September 4

Chromatography.

Dr. T. I. Williams.—*Some recent developments in chromatography.*

Dr. C. E. Dent.—*Partition chromatography with particular reference to amino-acid analysis.*

Dr. F. H. Pollard.—*Inorganic chromatography on cellulose.*

September 5

Chemical energy.

Prof. F. H. Garner, O.B.E.—*Introduction.*

Prof. F. H. Garner, O.B.E.—*Chemical energy of combustion reactions.*

Dr James Taylor, M.B.E.—*Chemical energy of reactions other than combustion*

Dr. H. J. T. Ellingham.—*Direc conversion of chemical energy to electrical energy.*

Prof. F. G. Gregory, F.R.S.—*The building up of chemical energy.*

September 6

Chemistry of muscular contraction (See Section I).

SECTION C

Geology

August 31

Prof. F. W. Shotton, M.B.E.—*The geology of the Birmingham district.*

The work of Charles Lapworth.

Prof. W. S. Boulton.

Prof. W. G. Fearnsides, F.R.S.

Dr. Gertrude L. Elles, M.B.E.

Dr. M. Macgregor.

September 1

The concealed coalfields of the English Midlands.

Prof. L. J. Wills.—*Introduction.*

Dr. G. M. Lees, F.R.S.—*Geological deductions from geophysical work bearing on the prospects of Coal Measures in the South Midlands area.*

Mr. T. Eastwood.—*The area between the South Staffordshire and Warwickshire coalfields.*

Prof. W. G. Fearnsides, F.R.S.—*The country around Cannock Chase and to the west and north of the South Staffordshire coalfield.*

Dr. G. H. Mitchell.—*The area east of the Warwickshire coalfield.*

The present position of the theory of continental drift (See Section K).

September 4

Stony meteorites, Presidential Address by Dr. W. Campbell Smith, C.B.E., M.C.

Mr. G. Mueller.—*The polymerization of hydrocarbons of Derbyshire by mineralizing solutions.*

Dr. F. Raw.—*The structure of the Malvern Hills.*

Mr. G. H. Jones.—*The Ordovician Rocks of the Western Berwyn Hills.*

September 5

Dr. F. Coles Phillips.—*Structural petrology and the interpretation of tectonics.*

Prof. J. G. C. Anderson.—*A newly mapped connection between the Leven schists of Lochaber and the mica-schists of Strathfindhorn.*

Mr. D. L. Dineley.—*The Old Red Sandstone of Clee Hills and the Welsh Borderland.*

Mr. F. H. T. Rhodes.—*British Lower Palaezoic conodont faunas.*

September 6

Dr. W. W. Black.—*A limestone knoll near Whitewell, Bowland.*

Dr. A. Lamont.—*The Ordovician and Devonian fossils from the Middle Bunter pebbles of the Midlands.*

Dr. A. W. Woodland, Mr. W. B. Evans and Mr. J. V. Stephens.—*The classification of the Coal Measures in South Wales.*

SECTION D

Zoology

August 31

The science and practice of entomology, Presidential Address by Dr. V. B. Wigglesworth, F.R.S.

Mr. J. D. Carthy.—*Home-finding in ants.*

Dr. R. S. Pitcher.—*The life-history of the raspberry cane midge*, Thomasiniana theobaldi *Barnes, and its relation to the fungal invasion of raspberry cane.*

Miss Muriel Sutton.—*The presence and significance of a peritrophic membrane in the* Corixidae (Hemiptera-heteroptera).

Water conservation in terrestrial arthropods.
Dr. V. B. Wigglesworth, F.R.S.—*Introduction.*
Dr. J. W. L. Beament.—*Water-proofing mechanisms in the eggs of arthropods.*
Dr. Eleanor H. Slifer.—*Conservation of moisture in the eggs of grasshoppers.*
Dr. A. D. Lees.—*Water-proofing and ecology.*
Dr. E. B. Edney.—*The water relations of woodlice.*

September 1

Functions of the skin of vertebrates (See Section I).
Present position of the theory of continental drift (See Section K).

September 4

Cytology and genetics in relation to the classification of plants and animals (See Section K.)

Prof. E. A. Spaul.—*The amphibian skin in relation to function and habitat.*
Dr. Anna Bidder.—*The digestive mechanism of* Nautilus.
Mr. E. R. Trueman.—*The bivalve hinge ligament.*
Mr. Colin Rees.—*Identification of lamellibranch larvae by hinge structure and the relation of larval to adult classification.*

September 5

Locusts and grasshoppers.
Dr. B. P. Uvarov, C.M.G., F.R.S.—*Introduction.*
Dr. Peggy E. Ellis.—*The marching behaviour of locust nymphs of the solitary and gregarious phases.*
Miss Z. Waloff.—*The migration of locusts.*
Dr. J. S. Kennedy.—*The problem of direction in desert locust migration.*
Dr. O. W. Richards.—*Methods of studying grasshopper populations.*
Mr. Ernest Neal.—*The badger.*

SECTION E

Geography

August 31

Geography of the Birmingham region.
Prof. R. H. Kinvig.—*Introduction.*
Mr. M. J. Wise, M.C.—*Development of Birmingham and its industries since 1750.*
Mr. B. L. C. Johnson.—*The early eighteenth-century iron trade in the Midlands.*
Mr. H. Thorpe.—*Factors influencing the growth of Lichfield.*

September 1

The upland plains of Britain; their origin and geographical significance, Presidential Address by Prof. S. W. Wooldridge.
Mr. A. J. Hunt.—*Land-use classifications for rural and urban surveys.*
Mr. D. N. Kendall.—*Mapping natural resources from the air.*
Present position of the theory of continental drift (See Section K).
Aspects of the geography of West Africa.
Mr. R. W. Steel.—*Some problems of population distribution in British West Africa.*
Mr. K. M. Buchanan.—*The regions of Nigeria.*

September 4

Mr. H. R. Jarrett.—*Problems of tropical agriculture with special reference to the Gambia.*
Miss M. Marshall.—*Some problems in Cyprus: geographical considerations.*
Geographical terminology.
Discussion initiated by Prof. E. G. R. Taylor (communication read by Dr. A. E. Moodie), Prof. R. H. Kinvig and Mr. E. O. Giffard.
Prof. S. H. Beaver.—*The geography of coke.*
Mr. H. A. Moisley.—*Some aspects of the North Staffordshire conurbation.*
Prof. K. C. Edwards.—*A new town in the Midlands: geographical considerations affecting the development of Corby.*

September 5

The pre-glacial evolution of the British land surface.
Prof. D. L. Linton.—*Some considerations bearing on the origin of the Midland drainage.*
Mr. G. T. Warwick, M.B.E.—*Denudation chronology of the limestone region of the Dove and Manifold valleys.*
Dr. Marjorie M. Sweeting.—*Pre-Glacial erosion stages in Burren, Co. Clare, Ireland.*
Mr. W. G. V. Balchin.—*Denudation chronology of the Exmoor region.*
Dr. J. F. Kirkaldy.—*The geologist's view of erosion surfaces.*
Mr. H. C. Brookfield.—*Some aspects of the geography of the English coastwise trade.*
Mr. E. Jones.—*Some aspects of studies of settlement in Britain.*

September 6

Prof. A. Davies.—*The false latitudes and longitudes of Columbus.*
Mr. D. J. Sinclair.—*Settled regions of the Ukraine.*

SECTION F

Economics

August 31

Mr. D. C. Rowan.—*The economic implications of the welfare state.*
Mr. F. N. Haden.—*The birth of a business man.*
Mr. R. H. B. Condie.—*The finance of the British social services.*

September 1

Economic progress—retrospect and prospect, Presidential Address by Prof. G. C. Allen.
Miss S. Marriner.—*The economic functions of the export merchant.*
Dr. K. G. Fenelon.—*The world's food supplies.*

September 4

Socio-psychological factors in productivity (See Section J).

September 5

Mr. P. Robson.—*Development Councils.*

Dr. H. S. Phillips.—*Factors determining the movement of industry: 1934–1950.*

SECTION G

Engineering

August 31

A chapter in bridge engineering a century ago, Presidential address by Prof. Andrew Robertson, F.R.S.

Dr. G. Roberts.—*Bridge engineering today and tomorrow.*

Prof. A. Tustin.—*Progress in automatic control systems.*

September 1

Presentation of technical information (Jointly with Sections A and J).

Prof. R. O. Kapp.—*General survey.*

Mr. L. Bainbridge-Bell.—*The need for clearer circuit diagrams.*

Mr. Geoffrey Parr.—*The technical author and his publisher.*

Miss M. D. Vernon.—*A psychologist's view.*

Mr. F. M. Colebrook.—*The administrative view.*

Gas turbines.

Prof. O. A. Saunders.—*Gas turbines for aircraft.*

Dr. A. T. Bowden.—*Some aspects of stationary gas turbines.*

Dr. J. S. Clarke, O.B.E.—*Combustion in gas turbines.*

Dr. J. Bronowski.—*Output problems in housebuilding.*

September 4

Mr. H. J. B. Harding and Dr. H. Q. Golder.—*Influence of soil mechanics on civil engineering practice.*

Mr. A. E. Russell.—*Aeroplane structures.*

Production engineering.

Prof. T. U. Matthew.—*Engineering production.*

Mr. F. G. Woollard.—*Flow line production.*

Dr. D. J. Desmond.—*Work measurement research.*

Mr. J. J. Gracie, C.B.E.—*Management approach to productivity.*

September 5

Papers by young engineers.

Dr. A. R. Flint.—*Stability and strength of slender beams.*

Dr. B. N. Cole.—*Recent developments in gas dynamics.*

Mr. J. G. Henderson.—*A new harmonic analyser and some applications.*

Agricultural engineering.

Prof. Ewen M'Ewen.—*Farm mechanisation and the agricultural engineer.*

Mr. W. J. West.—*Achievements in farm mechanisation.*

Mr. W. H. Cashmore.—*Future problems in farm mechanisation.*

SECTION H

Anthropology and Archaeology

August 31

The concept of culture.

Dr. Phyllis Kaberry.—*What is culture?*

Dr. Glyn E. Daniel.—*The concept of culture in prehistoric archaeology.*

Mr. E. L. Trist.—*Culture in psychological work.*

September 1

Prof. F. W. Shotton, M.B.E.—(i) *The geological aspects of archaeological settlements in the Midlands.* (ii) *The West Midland stone-axe survey.*

Mr. W. A. Seaby.—*Alcester and other Roman settlement-sites in the West Midlands.*

Miss J. M. Morris.—*The Anglo-Saxon material from East Warwickshire.*

Mr. P. L. D. Dry.—*Some aspects of Hausa family structure.*

Mrs. E. K. Miller.—*Nayar kinship in a changing economy.*

Mr. J. A. Barnes.—*History in a changing society.*

September 4

The influence of food plants on social structure, Presidential Address by Dr. R. N. Salaman, F.R.S.

Mr. I. H. Burkill.—*The rise and decline of the yam in the service of man.*

Prof. E. E. Evans.—*Lazy-bed cultivation and the rundale system in Ireland.*

The development of man's use of power.

Mr. B. A. L. Cranstone.—*Primitive man's use of power.*

Mr. A. Stowers.—*Some primitive applications of power to pumping and blowing.*

Mr. G. E. Fussell.—*Agricultural change and the English villager.*

September 5

Sir Leonard Woolley.—*Turkey as an archaeological province.*

Mr. D. B. Harden.—*Some problems of Maltese archaeology.*

Mr. H. H. Coghlan.—*Native copper in relation to prehistory.*

September 6

Dating the past (See Section A).

SECTION I

PHYSIOLOGY

August 31

Muscular movements.

Mr. W. Gissane.—*Introduction.*

Dr. H. D. Darcus.—*The force of muscular contraction.*

Mr. W. F. Floyd and Mr. P. H. S. Silver.—*Electromyographic studies of patterns of muscle activity in posture and movement.*

Dr. L. Guttman.—*Compensatory training in cases of paralysis of the skeletal muscles.*

September 1

Functions of the skin of vertebrates. (Jointly with Section D.)

Prof. P. B. Medawar, F.R.S.—*The anatomical basis of skin pigmentation.*

Dr. J. D. Findlay and Mr. W. R. Beakley.—*The function of the skin of domestic animals in heat dissipation.*

Dr. W. S. Bullough.—*The replacement of the skin.*

Dr. J. S. Weiner.—*The activity of sweat-glands in man.*

Prof. A. M. Boyd.—*Alterations in structure and functions of the skin seen in neuromuscular surgery.*

September 4

Hormones of the digestive tract.

Hormones of the digestive tract, Presidential Address by Prof. R. J. Brocklehurst.

Prof. A. A. Harper.—*The control of pancreatic secretion.*

Dr. R. B. Fisher.—*Activities of the intestinal mucosa.*

September 5

The nerve fibre.

Prof. J. D. Boyd.—*The structure of nerve fibres.*

Dr. A. L. Hodgkin, F.R.S.—*Nervous conduction.*

Dr. F. K. Sanders.—*Viruses and nerve cells.*

September 6

Chemistry of muscular contraction. (Jointly with Section B).

Prof. E. Baldwin.—*Introduction.*

Dr. S. V. Perry.—*Adenosinetriphosphate and the isolated myofibril.*

Dr. J. R. Bendall.—*Shortening of muscle during* rigor mortis.

SECTION J

PSYCHOLOGY

August 31

Mr. A. M. B. Rule and Mr. D. H. Bramley.—*Training in supervision and management.*

Mr. E. G. S. Evans.—*Attitude testing.*

Human affairs and the psychological point of view, Presidential Address by Dr. J. C. Flugel.

Mr. P. Smith.—*Psychological methods in vocational guidance—25 years of research.*

Dr. Joan Wynn Reeves.—*A vocational guidance scheme in Warrington.*

Mr. E. W. Hughes.—*Selection for further education in the mining industry.*

September 1

Presentation of technical information (See Section G).

Miss E. D. Fraser.—*Effects of home background on school achievement.*

Miss M. L. Kellmer.—*Intelligence, social maturity and environment.*

Prof. C. W. Valentine.—*Problem children and the concept of normality.*

Dr. C. L. C. Burns.—*Emotional states in adolescence.*

Prof. G. P. Meredith.—*Patterns of knowledge.*

Mr. G. E. R. Burroughs.—*The selection of students for teacher training.*

Dr. W. E. Flood.—*The scientific interests of adults.*

Prof. D. Katz.—*Composite portraiture and typology.*

September 4

Socio-psychological factors in productivity. (Joint session with Section F).

Prof. P. Sargant Florence.

Mr. R. Marriott.

Mr. R. G. Stansfield.

Dr. W. Baldamus.

September 5

Diagnosis and treatment of educational backwardness. (Joint session with Section L).

Miss M. M. Lindsay.—*Backwardness in the Primary School.*

Dr. W. D. Wall.—*Problems and methods of dealing with retardation in Junior Schools.*

Mrs. D. F. Vernon and Prof. P. E. Vernon.—*Investigations of the intelligibility of educational broadcasts.*

Mr. J. Trenaman.—*Effects of scientific broadcasts upon various educational levels in the population.*

Mr. A. E. Tubbs.—*Assessing the suitability of geography textbooks.*

SECTION K

BOTANY

August 31

Mr. J. G. Boswell.—*Some observations on the microbiology of acid soils.*

Dr. F. G. Meyer.—*Valeriana in North America and the West Indies.*

Prof. P. Maheshwari.—*Embryology in relation to plant taxonomy.*

Modern trends in the classification of plants, Presidential Address by Dr. W. B. Turrill.

September 1

The climatic limits of vegetation.

Prof. P. W. Richards.—*Climatic limits of the tropical rain forest.*

Prof. A. S. Boughey.—*The vegetation of the Nigerian Savannah Zones.*

Prof. A. Austin Miller.—*Accumulated temperature.*

Mr. James Macdonald.—*Climatic limitations in forestry in Great Britain.*

The chemistry of the cell with special reference to the nucleus. (Joint session with Section B.)

Prof. M. Stacey, F.R.S.—*The chemical composition of some cell nucleoproteins.*

Dr. W. G. Overend.—*The chemistry of the Feulgen and Dische reactions for cell nucleal material.*

Mr. L. F. La Cour.—*Heterochromatin in plants.*

Mr. I. Leslie.—*The cell nucleus in the biochemistry of tissue growth.*

The present position of the theory of continental drift. (Jointly with Sections C, D and E.)

Dr. J. R. F. Joyce.—*Continental drift and the Scotia Arc.*

Prof. J. H. F. Umbgrove.—*The case for the crust-substratum theory.*

Prof. R. D'O. Good.—*The distribution of the flowering plants in relation to theories of continental drift.*

Dr. H. E. Hinton.—*The distribution of animals.*

Prof. H. Jeffreys, F.R.S.—*Mechanical aspects of drift and alternative theories.*

Prof. S. W. Wooldridge.—*The bearing of late-Tertiary history on vertical and horizontal movements of the continents.*

September 4

Dr. G. Bond.—*The oxygen relation of leguminous root nodules.*

Dr. R. D. Williams.—*Mineral nutrition of grassland plants.*

Mr. A. D. Skelding.—*Some observations on salt absorption by storage tissue.*

Dr. E. S. Twyman.—*The iron and manganese requirements of plants.*

Mr. J. P. Cooper.—*Evolution of temperature and photoperiodic requirements in the genus* Lolium.

Cytology and genetics in relation to the classification of plants and animals. (Jointly with Section D.)

Mr. S. Muldal.—*Cytological studies in lumbbricid worms.*

Dr. B. N. Singh.—*Studies on the nuclear division in small free living amœbæ and its bearing on their classification.*

Mr. L. Sachs.—*Cytogenetics in relation to the systematics and phylogeny of the Triticinæ.*

Dr. J. P. Harding.—*The cytology of some crustacea as an aid to their classification.*

Prof. T. J. Jenkin, C.B.E.—*The breeding affinities of* Lolium *and* Festuca *in relation to the phylogeny of these genera.*

Col. F. C. Stern, O.B.E., M.C.—*Cytology as a factor in the taxonomy of flowering plants.*

Dr. E. K. Janaki-Ammal.—*Polyploidy in the genus* Rhododendron.

Dr. D. H. Valentine.—*The Experimental taxonomy of some species of* Viola *and* Primula.

Prof. W. Stiles, F.R.S.—*The green plant.*

September 5

The rehabilitation of derelict areas. (Jointly with Section M).

Sir John Russell, O.B.E., F.R.S.—*Rehabilitation of devastated land : the nature of the problems involved.*

Prof. S. H. Beaver.—*The physical nature and industrial background of derelict land.*

Mr. R. B. Beilby.—*Opencast quarry operations and the engineering problems created affecting the future treatment of land.*

Mr. W. Morley Davies.—*The rehabilitation of opencast mineral workings.*

Dr. W. J. Rees.—*The vegetation of derelict areas.*

Mr. R. W. B. Newton.—*The afforestation of opencast mining areas.*

SUB-SECTION K*

Forestry

August 31

Forestry in water catchment areas.

Mr. R. Mansell Prothero.—*Some aspects of the afforestation of upland water supply areas.*

Mr. D. Lloyd.—*The relation of run-off to afforestation in the Lake Vyrnwy catchment area.*

Mr. A. T. A. Learmonth.—*Forests and run-off during abnormal rainfall.*

Mr. A. E. Fordham.—*Afforestation in the Elan Valley gathering grounds of the City of Birmingham Water Department.*

September 1

Forest genetics.

Prof. Dr. B. Lindquist.—*The improvement of birch and the conception of elite trees in forest genetics.*

Dr. Syrach Larsen.—*Forest tree breeding based upon vegetative propagation.*

Mr. J. D. Matthews.—*Forest genetics research in Great Britain.*

September 4

Some problems of post-war forestry, Chairman's Address, by the Rt. Hon. Lord Bolton.

Sir Richard Cotterell, Bt.—*The planting of hardwoods in mixture.*

Mr. Bruce Urquhart.—*The management of private woodlands by co-operative methods.*

SECTION L

Education

August 31

Mr. R. Birley.—*Economic determinism and education.*

September 1

Education and power, Presidential Address by Mr. W. F. Oakeshott.

Dr. Eric James.—*Science in the general education of the non-scientist.*

September 4

Sir Ewart Smith.—*The critical importance of higher technological education in relation to industrial productivity.*

Mr. Walter Adams.—*Higher education in colonial areas.*

September 5

Diagnosis and treatment of backwardness in the primary school (See Section J).

September 6

Dr. A. G. Lowndes.—*Carrying out of research in schools and its influence on teaching.*

SECTION M

AGRICULTURE

August 31

Quality in agriculture, Presidential Address by Prof. H. D. Kay, C.B.E., F.R.S.

Quality in grassland.

Dr. W. Davies.—*Quality in grassland.*

Mr. D. H. Curnow.—*The occurrence of oestrogens in plant material and their effects on animals.*

September 1

Factors limiting food production in Britain.

Sir James A. Scott Watson, C.B.E.—*Factors limiting food production in Britain: physical factors.*

Mr. W. B. Mercer, C.B.E.—*Extension work.*

September 4

Recent developments in plant protection.

Mr. C. P. Norbury.—*Introduction.*

Dr. W. E. Ripper.—*Systemic insecticides open new fields of pest control.*

Prof. R. L. Wain.—*Some biological properties of aryloxyaliphatic acids in relation to chemical structure.*

Dr. M. C. Vyvyan.—*Fruit drop and its control.*

September 5

Rehabilitation of derelict areas (See Section K).

RESEARCH COMMITTEES, 1950–51

Grants of money, if any, from the Association for expenses connected with researches are indicated in heavy type.

SECTION A.—MATHEMATICS AND PHYSICS.

Seismological investigations.—Dr. R. Stoneley, F.R.S. (*Chairman*), Lt.-Col. E. Tillotson (*Secretary*), Mr. E. F. Baxter, Miss E. F. Bellamy, Prof. P. G. H. Boswell, O.B.E., F.R.S., Mr. B. C. Browne, Dr. E. C. Bullard, F.R.S., Dr. K. F. Chackett, Dr. G. E. R. Deacon, F.R.S., Dr. A. T. J. Dollar, Rev. H. Norman Edge, Dr. A. E. M. Geddes, O.B.E., Prof. G. R. Goldsbrough, C.B.E., F.R.S., Mr. M. N. Hill, Dr. O. J. R. Howarth, O.B.E., Mr. J. S. Hughes, Prof. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Mr. E. N. Lawrence, Dr. A. W. Lee, Prof. J. Proudman, F.R.S., Dr. A. O. Rankine, O.B.E., F.R.S., Rev. C. Rey, S.J., Dr. G. D. Robinson, Mr. H. V. Shaw, Sir Frank Smith, G.C.B., G.B.E., F.R.S., Dr. P. L. Willmore.

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (*Chairman*), Prof. L. R. Moore (*Secretary*), Sir Edward Bailey, M.C., F.R.S., Mr. J. L. Begg, Mr. W. S. Bisat, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. H. Cox, Mr. E. E. L. Dixon, Prof. W. G. Fearnsides, F.R.S., Prof. H. L. Hawkins, F.R.S., Prof. G. Hickling, F.R.S., Dr. R. G. S. Hudson, Prof. V. C. Illing, F.R.S., Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Mr. T. G. Miller, Dr. F. J. North, Prof. F. W. Shotton, M.B.E., Dr. W. E. Swinton, Dr. F. S. Wallis, Prof. D. M. S. Watson, F.R.S., Prof. T. S. Westoll, Mr. T. H. Whitehead, Prof. W. F. Whittard, Prof. S. W. Wooldridge. **£20.**

To consider and report on questions affecting the teaching of geology in schools.—Dr. A. E. Trueman, F.R.S. (*Chairman*), Dr. Mabel E. Tomlinson (*Secretary*), Miss M. A. Arber, Mr. A. Bray, Prof. A. H. Cox, Miss Gaynor Evans, Prof. W. G. Fearnsides, F.R.S., Prof. T. N. George, Prof. G. Hickling, F.R.S., Prof. D. E. Innes, Prof. D. Leitch, Prof. L. R. Moore, Prof. W. J. Pugh, Dr. K. S. Sandford, Dr. H. Dighton Thomas, Dr. A. K. Wells, Prof. A. Wood.

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. H. L. Hawkins, F.R.S. (*Chairman*), Mr. G. S. Sweeting (*Secretary*), Mr. H. Ashley, Mr. G. M.

Davies, Mr. W. G. Hardie, Dr. N. Holgate, Mr. G. S. Johnstone, Dr. A. G. MacGregor, Dr. F. J. North, Mr. J. Ranson, Prof. W. F. Whittard.

SECTIONS D, K.—ZOOLOGY, BOTANY.

To consider the position of biology and rural science in the school curriculum and matters relating thereto.—Prof. L. J. Audus (*Chairman*), Dr. L. M. J. Kramer (*Secretary*), Mr. F. H. C. Butler, Mr. W. J. Heasman, Prof. C. T. Ingold, Prof. H. W. Miles, Dr. G. E. Newell, Mr. A. C. Penney, Mr. W. B. Yapp. **£10.**

Co-ordinating committee for Cytology and Genetics. Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. J. L. Crosby (*Secretary*), Dr. D. G. Catcheside, Prof. F. A. E. Crew, F.R.S., Dr. C. D. Darlington, F.R.S., Dr. E. B. Ford, F.R.S., Dr. J. Hammond, F.R.S., Prof. T. J. Jenkin, Dr. P. C. Koller, Prof. I. Manton, Prof. K. Mather, F.R.S., Prof. L. S. Penrose, Dr. G. Pontecorvo, Dr. R. R. Race, Dr. P. T. Thomas, Dr. W. B. Turrill, Prof. C. H. Waddington, F.R.S. **£5.**

SECTION E.—GEOGRAPHY.

To collect records of the revival of Geography in the British Isles dating from the later years of the nineteenth century.—Mr. J. N. L. Baker (*Chairman*), Mr. T. W. Freeman (*Secretary*), Prof. H. C. Darby, Prof. W. G. East, Dr. O. J. R. Howarth, O.B.E., Prof. D. L. Linton, Prof. A. G. Ogilvie, O.B.E., **£5.**

To collect and record information on demography and seasonal activities in relation to environment in Inter-Tropical Africa.—Prof. A. G. Ogilvie, O.B.E. (*Chairman*), Mr. R. W. Steel (*Secretary*), Prof. S. J. K. Baker, Mr. K. Buchanan, Dr. R. J. Harrison-Church, Prof. F. Debenham, O.B.E., Prof. C. Daryll Forde, Dr. E. J. Howell, Mr. D. B. Mather, Dr. R. Miller, Prof. W. J. Varley, Prof. J. H. Wellington. **£5.**

To prepare a glossary of geographical terms with agreed definitions in English including reference to origin and previous usage and to current use and misuse.—Prof. E. G. R. Taylor (*Chairman*), Prof. S. W. Wooldridge (*Secretary*), Prof. W. G. East, Mr. E. O. Giffard, M.B.E., Mr. A. F. Martin, Dr. C. J. Robertson, Mr. A. E. Smailes, Mr. J. C. Swayne, Mr. G. T. Warwick.

SECTION H.—ANTHROPOLOGY.

To co-operate with the Torquay Natural History Society in investigating Kents Cavern.—Mr. M. C. Burkitt (*Chairman*), Prof. F. E. Zeuner (*Secretary*), Mr. A. L. Armstrong, Prof. V. G. Childe, Prof. D. A. E. Garrod, Mr. A. G. Madan, Dr. K. P. Oakley, Mr. E. Pyddoke.

To co-operate with a committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district.—Mr. M. C. Burkitt (*Chairman*), Mr. A. Leslie Armstrong (*Secretary*), Dr. Arthur Court, Prof. H. J. Fleure, F.R.S., Prof. D. A. E. Garrod, Mr. W. H. Hanbury, Dr. J. Wilfred Jackson, Mr. R. U. Sayce.

To report on the composition of ancient metal objects.—Prof. V. Gordon Childe (*Chairman*), Dr. C. H. Desch, F.R.S. (*Secretary*), Mr. C. E. N. Bromehead, Mr. H. H. Coghlan, Prof. H. J. Fleure, F.R.S., Prof. C. F. C. Hawkes, Prof. M. E. L. Mallowan, Mr. H. Maryon.

To carry out research among the Ainu of Japan.—Mrs. C. G. Seligman (*Chairman and Secretary*), Rt. Hon. Lord Raglan, Mr. Arthur Waley.

To reinvestigate the Bury St. Edmunds skull site.—Mr. M. C. Burkitt (*Chairman*), Dr. K. P. Oakley (*Secretary*), Mr. A. Leslie Armstrong, Mr. D. F. W. Baden-Powell, Prof. V. Gordon Childe. **£15.**

To study the history and ethnology of sheep farming and farmers in the Cheviots.—Mr. R. U. Sayce (*Chairman and Secretary*), Mr. A. Leslie Armstrong, Mr. M. C. Burkitt, Prof. I. A. Richmond, Dr. R. N. Salaman, F.R.S., Dr. R. K. Schofield.

To consider the possibility of archaeological work on vacant sites in the city of Leicester.—Prof. I. A. Richmond (*Chairman*), Mr. D. B. Harden (*Secretary*), Mr. A. Leslie Armstrong, Mr. D. D.-T. Clarke, Mr. K. D. M. Dauncey.

REPORT OF COUNCIL TO THE GENERAL COMMITTEE, 1949–50

Presented on August 30, 1950.

Obituary

1. Since the last report the Association has suffered the loss of the following office bearers and supporters :

Dr. J. A. Bowie
Prof. J. A. Crowther
Prof. C. S. Gibson, O.B.E., F.R.S.
Sir Norman Haworth, F.R.S.
Sir James Henderson
Lady Henderson
Prof. H. Gordon Jackson
Prof. S. H. Reynolds
Prof. G. W. Robinson, C.B.E., F.R.S.
Dr. H. Shaw
Mr. A. J. Wilmott

Relations with other Institutions

2. With Institutions at home the Association has maintained cordial relations through official representatives and in other ways. There have been no changes in the standing representation of the Association in the work of other bodies. Fresh contacts have been made by the appointment of Sir Richard Paget as a member of the governing body of the new Institute of Recorded Sound, and by the appointment of Prof. H. J. Fleure and Mr. D. B. Harden to represent the Association on the Council for British Archæology. Prof. Winifred Cullis represented the Association at the Annual Conference of the Institute of Adult Education, held at Bath. The President represented the Association at the Jubilee Celebrations of the University of Birmingham in May.

3. As regards Institutions overseas, the Council has been concerned mainly with Associations for the Advancement of Science on which there is a fuller note below. The attendance of representatives of the International Unions at the Newcastle Meeting was so encouraging that the Council has repeated the invitations for 1950.

The Council has appointed the following representatives at International meetings : International Congress of Microbiology (Rio de Janeiro), Dr. John Ramsbottom ; International Congress of Mathematicians (Cambridge, Mass.), Dr. D. Pedoe, Mr. John Todd, Dr. Olga Todd and Dr. Dorothy Wrinch.

4. At every meeting of the Council during the past year consideration has been given to the proposal, originating in the French Association and sponsored by UNESCO, that there should be established a World Federation of Associations for the Advancement of Science. Opinions on this matter have been collected by UNESCO from the principal Associations and will be discussed at a meeting in Paris on September 8 and 9 which Sir Richard Southwell will attend. The Council has not, so far, been convinced that such a Federation would achieve anything which could not be done by existing organisations and has communicated this view to UNESCO together with a recommendation that the most effective way for UNESCO to strengthen co-operation between Associations for the Advancement of Science would be to assist the interchange of representatives by making grants of money for that purpose. The Association was represented at the Annual Meeting of the American Association (in New York) by Dr. G. B. B. M. Sutherland, and of the Pakistan Association (in Karachi) by Dr. Edward Hindle. The French Association will hold their Annual Meeting in Toulouse in September and the Association will be represented by Sir Richard Southwell.

5. The Association has continued to be represented on the British Committee for Co-operation with UNESCO in the Natural Sciences. At the request of the Science Division of UNESCO, and with the approval of the Council, a report on Science Clubs for Young People in Britain was prepared and sent to UNESCO as a contribution towards further study of this method of stimulating interest in Science.

Finance

6. The General Treasurer has kept the Council informed of the state of the Association's finances, and his Statement and Account for the financial year ending on March 31, 1950 will be submitted to the General Committee.

Future Meetings

7. At the last meeting of the General Committee invitations were accepted from Belfast (1952) and Liverpool (1953). The Council will make a recommendation as to the date of the 1952 meeting.

8. As regards the meeting in Edinburgh in 1951 (August 8–15) under the Presidency of H.R.H. The Duke of Edinburgh, the Council have assured the organisers of the Festival of Britain that the programme will include items dealing with British contributions to the progress of science and its applications since 1851. In view of the need to be ready with information which can be included in the Festival of Britain publicity, and in order that programmes of Sections may have the longest possible consideration, the Council have advanced the normal date of appointment of Presidents of Sections, and are able to report that the following have accepted office :

Section A (Mathematics and Physics), Sir David Brunt, F.R.S. ; B (Chemistry), Sir Cyril Hinshelwood, F.R.S. ; C (Geology), Prof. W. B. R. King, O.B.E., F.R.S. ; D (Zoology), Dr. C. F. A. Pantin, F.R.S. ; E (Geography), Dr. O. J. R. Howarth, O.B.E. ; F (Economics), Prof. R. G. Hawtrey ; G (Engineering), Sir Claude Gibb, C.B.E., F.R.S. ; H (Anthropology and Archæology), Sir Cyril Fox ; I (Physiology), Prof. H. P. Gilding ; J (Psychology), Dr. C. A. Mace ; K (Botany), Prof. W. Brown, F.R.S. ; L (Education), Sir Hector Hetherington ; M (Agriculture), Dr. E. M. Crowther.

Officers and Council

9. *President*, 1951.—H.R.H. The Duke of Edinburgh has been pleased to accept this office.

10. *General Officers*, 1950–51.—The Council recommend that the present Officers be reappointed :

General Treasurer : Mr. M. G. Bennett.
General Secretaries : Dr. Edward Hindle, F.R.S., and Sir Richard Southwell, F.R.S.

11. On November 4, 1949, under discretion given by the General Committee on August 31, 1949, the Council decided not to re-elect Prof. J. D. Bernal to the seat on the Council which had been left vacant by the General Committee. The papers before the Council when this decision was taken were published in *The Advancement of Science*, Vol. VI, No. 24, pp. 388–91.

12. *Other Members of Council.*—On May 26, the Council appointed Dr. Norman C. Wright a member of Council. The members retiring under Statute III, 3, are : Sir Edward Appleton, Prof. David Burns, Prof. P. Sargant Florence, Prof. E. H. Neville, and Prof. R. G. White.

The Council nominate for appointment : Prof. G. C. Allen, Prof. H. P. Gilding and Sir Harold Spencer Jones, leaving two vacancies in the ordinary membership to be filled by the General Committee without nomination by the Council. As the names provide for the statutory minimum representation of each Section the two remaining places can be filled by representatives of any Section. The full list of nominations is as follows :

Prof. G. C. Allen
Prof. F. Balfour-Browne
M. C. Burkitt
P. Ritchie Calder, C.B.E.
Wing-Comm. T. R. Cave-Browne-Cave, C.B.E.
Prof. H. G. Champion, C.I.E.
Prof. Winifred Cullis, C.B.E.
Sir Alfred Egerton, F.R.S.
Dr. K. G. Fenelon
Dr. J. C. Maxwell Garnett, C.B.E.
Prof. H. P. Gilding
Dr. Ezer Griffiths, F.R.S.
D. B. Harden
Dr. O. J. R. Howarth
Sir Harold Spencer Jones, F.R.S.
Sir William Ogg
Dr. S. J. F. Philpott, M.C.
Rt. Hon. Lord Rennell of Rodd, K.B.E., C.B.
Sir John Simonsen, F.R.S.
Prof. W. O. Lester Smith, C.B.E.
Prof. L. Dudley Stamp, C.B.E.
Dr. C. J. Stubblefield, F.R.S.
Dr. H. Hamshaw Thomas, M.B.E., F.R.S.
Dr. C. Tierney
Dr. A. E. Trueman, F.R.S.

Dr. H. E. Wimperis, C.B., C.B.E.	Prof. A. W. Wolters
	Dr. N. C. Wright

13. *Honorary Auditors*, 1950–51.—The Council recommend the reappointment of Dr. H. S. Rowell, O.B.E., and Mr. R. S. Whipple.

General Committee

14. The following have been admitted as members of the General Committee on the recommendation of Sectional Committees :

Mr. A. H. G. Alston	Prof. K. Mather
Prof. L. J. Audus	Prof. H. S. Ruse
Prof. L. F. Bates	Dr. E. W. Russell
Mr. J. G. Boswell	Mr. L. Slater
Prof. R. Dennell	Dr. H. Dighton Thomas
Prof. K. C. Edwards	Dr. Trevor Williams
Prof. Alastair Graham	

Research

15. Following the Newcastle Meeting, the Council appointed 19 Research Committees on the recommendation of Sections. They are listed in *The Advancement of Science*, Vol. VI, No. 24, p. 387. From funds under their control the Council approved the following grants to 13 of those Committees :

Committee	*Grant*	*Fund*
	£	
Critical Geological Sections	20	Hobson
*Plymouth Laboratory	50	Caird
*Zoological Record	50	,,
*Freshwater Biological Station, Windermere	50	,,
Naples Station	50	,,
Cytology and Genetics	5	Haydock
Revival of Geography in Nineteenth Century	5	Caird
Urban Geography	3	,,
Inter-Tropical Africa	5	,,
Kent's Cavern	10	,,
Bury St. Edmund's Skull Site	15	,,
Sheep Farming in the Cheviots	25	,,
Biology in the School Curriculum	5	Haydock

16. In the revised Statutes, as approved by the General Committee on April 13, 1945, provision was made for a 5-year limit to the payment of grants for research. This new rule took effect from the year 1945–46, with the result that the year 1949–50 was the last in which (under the rule) grants could be paid for some of the work listed above. The subjects affected are marked with an asterisk.

Meetings and Lectures

17. The Division for Social and International Relations of Science has not held any meetings during the year, but has arranged for the Birmingham Meeting a session on ' The Dearth of Science Teachers.' Through the Division the Association will collaborate with the Institute of Biology and the Atomic Scientists' Association in a two-day conference in London on ' The Biological Hazards of Atomic Energy.'

18. The Norman Lockyer Lecture for 1949 was delivered on November 14 at Birmingham by Prof. Herbert Dingle, who spoke on ' Modern Theories on the Origin of the Universe.' Prof. C. F. Powell has been appointed to deliver the lecture in 1950, in Edinburgh. Sir Lawrence Bragg has accepted an invitation to give the Radford Mather Lecture in London ; and the Alexander Pedler Lecture was delivered on May 26 by Mr. W. E. V. Young who spoke on ' Avebury Circle ' to the members of the South Western Naturalists' Union during their Annual Meeting at Marlborough.

By invitation of the American Association, Dr. Gordon B. B. M. Sutherland delivered the British-American Association Lecture during the Annual Meeting of the American Association in New York. His subject was ' The growing importance of infra-red studies in physics, chemistry and biology.'

Publications

19. *The Advancement of Science* has been published at regular quarterly intervals and the circulation has remained at about 3,000 copies. During the year the Council has had occasion to reconsider the publication dates and has altered them from the last Friday of October, January, April and July to the first Friday of June, September, December and March. It was not possible to make this alteration suddenly and the change has been made in stages. The new phasing will begin with the issue for September 1950.

Copyright

20. The Council have subscribed to the Royal Society's Fair Copying Declaration and by doing so have declared that, under

certain conditions, they will regard it as fair dealing for the purpose of private study or research when a non-profit-making organisation such as a library, archives office, museum or information service makes a single reproduction of a part of an issue of the Association's publications. This merely affects the making of single copies for study. The Council still requires individual applications to be made for permission to reprint material contained in the Association's publications.

Resolutions and Recommendations

21. Following discussions at the Newcastle Meeting the Council received and considered a number of resolutions and recommendations with the following results :

(i) *Derbyshire Caves.* The Council agreed that the material collected by Mr. A. L. Armstrong from Derbyshire Caves should be presented to the Manchester Museum.

(ii) *Maps of the Roman Empire.* As a result of representations made by Section H (with support from Section E) a Committee of the Society of Antiquaries was formed to take action towards further work on the Tabula Imperii Romani. The Council made a token grant of £10 as a contribution towards the cost of producing a map of Roman Libya.

(iii) *Geographical Terminology.* Pending further discussion at Birmingham, no action was taken on a recommendation to the effect that the Association should invite the specialist geographical societies in Britain to take action with regard to geographical terminology.

(iv) *Technical Skills.* Secretaries of Corresponding Societies were asked to enquire and report whether any of their members who had technical skills such as section making, photo micrography, etc., would be prepared to help research workers who had need of skilled assistance.

(v) *Abstracts.* Secretaries of Corresponding Societies with Journals in which original work is reported were invited to arrange that authors should provide 200-word summaries of their papers for publication with the full text.

(vi) *List of Societies.* The Secretary was instructed to publish in *The Advancement of Science* up-to-date lists of the Societies in correspondence with the Association.

Prizes

22. *South Africa Medal.* The Council approved the award of the British Association Medal by the South African Association to M. J. Toerien for his original paper on 'The Cranial Morphology of the Californian Lizard.'

23. *Endeavour Prizes.* In connection with the Birmingham Meeting the Council have accepted a generous offer by Imperial Chemical Industries, Ltd., publishers of the Quarterly Scientific Review, *Endeavour*, to provide the sum of 85 guineas to be awarded in prizes of 50, 25 and 10 guineas for scientific essays by candidates not older than 25 years. A choice of twelve subjects was offered and 117 essays were received by the closing date. The prize winners will be announced at the Birmingham Meeting and the essay winning the first prize will be published in *The Advancement of Science*.

24. *Exhibitioners Essay Prize.* As an experiment for one year the Council have decided to offer a prize of £10 for the best essay on the Birmingham Meeting submitted by a Student Exhibitioner.

Down House

25. The number of visitors to the Darwin Memorial at Down House during 1949 was 4,306, as compared with 3,768 in 1948 and 3,497 in 1947. These figures show an encouraging increase over the past two years, but the total is still far short of the pre-war number of visitors which was of the order of 7,000.

26. Records of rainfall have been maintained and show that precipitation in 1949 was 24·99 ins., which was 6·41 ins. below the average recorded there over the previous 12 years.

27. One of the pictures placed at Down House by the late Sir Buckston Browne, *The Blacksmith's Forge* by Joseph Wright, was lent to the British Council for an exhibition of paintings of the British School

(1730–1850). The exhibition, which comprised 120 works, visited Hamburg, Oslo, Stockholm and Copenhagen and was seen by more than 100,000 people.

28. The Council reported last year the appointment of a Committee to consider and report on proposals for increasing the usefulness of Down House as a scientific centre. Of several proposals put forward one seemed to give more hope than the others. It is a proposal that, without interfering unduly with the memorial rooms, the House might be used as a residential centre for the study of the natural sciences by adults and senior pupils in grammar schools, the centre to be established and maintained jointly by the University of Oxford (extra-mural Delegacy), the Kent Education Committee and the British Association. The Council approved the proposal in principle for discussion with the other bodies concerned. The result at the time of writing this report is that the University of Oxford and the Kent Education Committee have also approved the scheme in principle and, subject to the concurrence of the Kent County Council, a more detailed scheme will be prepared for future consideration.

GENERAL TREASURER'S STATEMENT AND ACCOUNT, 1949–50

THE main point about the attached accounts is that the deficit on the General Account was reduced to £401, compared with £1,247 in the previous year, despite increases in salaries and other essential expenses. While this is an improvement, it is not, of course, satisfactory yet. From a review of the trends of recent years, it appears that both expenditure and income are increasing at such a rate that the Association should aim at an income of £10,000 p.a. within a few years, even if it does not launch out into any new services for the advancement of science.

This can be done if a sufficient number of members with a continuing interest in the Annual Meetings make use of the concession, accepted by the Inland Revenue, by which the Association can recover Income Tax on covenanted subscriptions. It is therefore very strongly urged that all members who attend more or less regularly will do this. It will cost them nothing and will materially help in the work of the Association.

It is hoped that it will not be necessary much longer to meet substantial annual deficits in the Down House Account by reducing the endowment fund capital. Progress has been made with negotiations for the extended use of Down House as can be seen in the Council's Report to the General Committee.

M. G. BENNETT,
General Treasurer.

Balance Sheet, 31st March, 1950

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES

	£ s. d.	£ s. d.
General Purposes:—		
Sundry Creditors	749 11 9	
Amounts received in advance for publications	191 2 2	
Membership and Associateship subscriptions in advance	199 7 0	1,140 0 11
Accumulated Fund		
As per last Account	42,350 6 5	
Less Excess of Expenditure over Income for the year on General Account 401 0 7		
Loss on Stock transferred to Development Fund Account 9 16 0		
	410 16 7	
	41,939 9 10	
Add, Legacy by Mr. J. R. Solly, 1948		
As per last Account 2,711 1 11		
Balance received during year 273 11 11		
	2,984 13 10	44,924 3 8
Life Membership Compositions		
As per last Account	6,045 10 4	
Add Subscriptions received during year	210 0 0	
	6,255 10 4	
Less Amount transferred to Income and Expenditure Account	10 10 0	6,245 0 4
[52,009 17 1]		52,309 4 11
Development Fund		
As per last Account	5,900 0 0	
Add Excess of Income over Expenditure for the year	140 5 11	
[5,900 0 0]		6,040 5 11
Special Purposes:—		
Caird Fund		
Capital	9,928 17 9	
Income and Expenditure Account balance as per last Account 481 15 8		
Add Excess of Income over Expenditure for the year 23 5 6		
	505 1 2	
[10,410 13 5]		10,433 18 11
Toronto University Presentation Fund		
Capital	178 11 4	
Income and Expenditure Account balance as per last Account 5 6 3		
Less Excess of Expenditure over Income for the year 1 6		
	5 4 9	
[183 17 7]		183 16 1
Bernard Hobson Fund		
Capital	1,093 2 6	
Income and Expenditure Account balance as per last Account 333 6 4		
Add Excess of Income over Expenditure for the year 32 9 1		
	365 15 5	
[1,426 8 10]		1,458 17 11
Leicester and Leicestershire Fund, 1933		
Capital	1,000 0 0	
Income and Expenditure Account balance as per last Account 136 0 8		
Add Excess of Income over Expenditure for the year 30 15 9		
	166 16 5	
[1,136 0 8]		1,166 16 5
Radford Mather Lecture Fund		
Capital	250 0 0	
Income and Expenditure Account balance as per last Account 36 16 1		
Add Excess of Income over Expenditure for the year 6 14 5		
	43 10 6	
[286 16 1]		293 10 6
[71,353 13 8] Carried forward		71,886 10 8

ASSETS

	£ s. d.	£ s. d.
General Purposes:—		
Investments as scheduled with Income and Expenditure Account, No. 1	52,063 8 8	
Sundry debtors	144 4 10	
Cash at bank	101 11 5	
[52,009 17 1]		52,309 4 11
Development Fund		
Investments (see Income and Expenditure Account No. 2)	5,952 6 0	
Cash at bank	87 19 11	
[5,900 0 0]		6,040 5 11
Special Purposes:—		
Caird Fund		
Investments (see Income and Expenditure Account, No. 3)	9,928 17 9	
Cash at bank	505 1 2	
[10,410 13 5]		10,433 18 11
Toronto University Presentation Fund		
Investment (see Income and Expenditure Account, No. 4)	178 11 4	
Cash at bank	5 4 9	
[183 17 7]		183 16 1
Bernard Hobson Fund		
Investments (see Income and Expenditure Account, No. 5)	1,243 2 6	
Cash at bank	215 15 5	
[1,426 8 10]		1,458 17 11
Leicester and Leicestershire Fund, 1933,		
Investments (see Income and Expenditure Account, No. 6)	1,000 0 0	
Cash at bank	166 16 5	
[1,136 0 8]		1,166 16 5
Radford Mather Lecture Fund		
Investment (see Income and Expenditure Account, No. 7)	250 0 0	
Cash at bank	43 10 6	
[286 16 1]		293 10 6
[71,353 13 8] Carried forward		71,886 10 8

Balance Sheet, 31st March, 1950 (*continued*)

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

LIABILITIES (*continued*)

		£ s. d.	£ s. d.
[71,353 13 8]	Brought forward		71,886 10 8
	Arthur Haydock Bequest (1945)		
	Capital	2,215 12 0	
	Income and Expenditure Account balance as per last Account . 237 18 6		
	Add Excess of Income over Expenditure for the year . . . 60 16 9		
		298 15 3	
[2,453 10 6]			2,514 7 3
	Gift (1946) for research in memory of Miss J. R. Corcoran . .		100 0 0
[100 0 0]			
	Down House		
	Endowment Fund as per last Account	19,167 8 0	
	Less Excess of Expenditure over Income for the year . . . 628 11 1		
	Less on stock transferred for cash, to Haydock and Corcoran Funds 41 4 7		
		669 15 8	
		18,497 12 4	
	Library Fund as per last Account . . 10 10 0		
	Less Expenditure during the year . . . 6 18 8		
		3 11 4	
	Sundry Creditors . . .	50 17 8	
[19,183 5 7]			18,552 1 4
[93,090 9 9]			£93,052 19 3

ASSETS (*continued*)

		£ s. d.	£ s. d.
[71,353 13 8]	Brought forward		71,886 10 8
	Arthur Haydock Bequest		
	Investments (see Income and Expenditure Account, No. 8) .	2,465 12 0	
	Cash at bank	48 15 3	
[2,453 10 6]			2,514 7 3
	Gift (1946) for research in memory of Miss J. R. Corcoran—		
	Investment: £144 18*s.* 6*d.* Consolidated 2½% Stock (Inscribed) . . (Value at 31.3.50, £100)		100 0 0
[100 0 0]			
	Down House		
	Investments (see Income and Expenditure Account, No. 9) .	18,405 4 10	
	Sundry Debtors	10 17 0	
	Catalogues in stock, at cost . .	39 9 0	
	Cash at bank	37 16 8	
	Cash in hand	58 13 10	
[19,183 5 7]			18,552 1 4
[93,090 9 9]			£93,052 19 3

We have examined the foregoing Account with the Books and Vouchers and certify the same to be correct. We have also verified the Balance at the Bankers and the Investments, and have inspected the Deeds of Down House.

Approved:
ROBERT S. WHIPPLE
H. S. ROWELL } *Auditors.*

W. B. KEEN & CO., *Chartered Accountants*,
Finsbury Circus House, E.C. 2.
12th July, 1950.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31st MARCH, 1950

No. 1. General Income and Expenditure

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£7,011 8*s.* 2*d.* Consolidated 2½ per cent. Stock (Inscribed)	5,401 3 0
	£1,252 16*s.* 2*d.* Consolidated 2½ per cent. Stock (Registered)	1,000 0 0
	£4,068 19*s.* 0*d.* 3 per cent. Savings Bonds 1955/65	4,088 19 0
	£1,808 0*s.* 0*d.* 3 per cent. Savings Bonds 1960/70	1,816 1 8
	£18,400 0*s.* 0*d.* 3 per cent. Savings Bonds, 1965/75	19,098 11 9
	£52 12*s.* 7*d.* 3½ per cent. War Stock (Post Office issue)	54 5 2
	£7,704 6*s.* 2*d.* 3½ per cent. War Stock, 1952 or after	7,840 0 9
	£6,768 15*s.* 7*d.* 3½ per cent. Conversion Stock, 1961 or after	5,726 8 11
	£4,184 18*s.* 2*d.* 2½ per cent. Treasury Stock, 1975 or after	4,184 18 2
	£1,400 0*s.* 0*d.* 4 per cent. Funding Loan Stock, 1960/90	1,622 0 0
	£981 10*s.* 0*d.* 4 per cent. Commonwealth of Australia Stock 1955/70	1,000 0 0
	£125 3*s.* 9*d.* 3 per cent. British Transport Stock, 1978/88	125 0 0
	£100 0*s.* 0*d.* 3 per cent. Defence Bonds	101 0 3
	Post-war Credit, J. R. Solly, deceased	5 0 0
	[*Value of stocks at 31/3/49, £52,776 12s. 7d.*] (Value at 31/3/50, £47,486 10*s.* 9*d.*)	
[*51,873 0 8*]		£52,063 8 8

EXPENDITURE

	£ s. d.	£ s. d.
To Heat, Lighting and Power		89 19 0
„ Stationery		338 1 6
„ Rent		1 0 0
„ Postages		369 16 3
„ Telephone		29 17 7
„ Insurances		9 16 3
„ Travelling expenses		500 6 2
„ Audit for 1948–49		84 0 0
„ Exhibitioners :	121 19 3	
Less Liverpool University grants	9 0 0	
		112 19 3
„ Subscription to Parliamentary and Scientific Committee		10 10 0
„ Hire of meeting rooms, equipment, etc.		26 6 2
„ Copying, etc., by outside offices		5 5 4
„ Lift Inspection and Repairs		31 12 0
„ Carriage		16 4 5
„ Reference books, press cuttings, etc.		57 0 5
„ General expenses		55 18 1
„ Panels of armorial bearings		12 9 6
„ Salaries, wages, pensions and National Insurance		3,876 6 0
„ Printing, etc.—		
"The Advancement of Science"	1,986 5 6	
Miscellaneous	1,179 0 11	
		3,165 6 5
„ Norman Lockyer Lecture, 1949 : Fee		10 10 0
„ Hospitality		127 17 9
„ Membership badges		33 6 0
„ Legal advice		3 3 0
„ Payment to Royal Anthropological Institute in respect of "Notes and Queries on Anthropology"		48 0 0
„ Subsciption to International Union for the Protection of Nature		5 0 0
[*8,721 0 0*]		£9,020 11 1

INCOME

	£ s. d.	£ s. d.
By Annual subscriptions		4,751 13 6
„ Life Compositions : amount transferred on expiry of membership		10 10 0
„ Sale of Publications		718 18 1
„ Advertisements in B.A. publications		1,217 7 0
„ Income Tax recovered to 31st March, 1949		21 5 1
„ Interest on Investments		1,727 5 6
„ Charges for administration of Special Funds		159 4 10
„ Donations		13 6 2
[*7,473 11 2*]		8,619 10 6
By Balance, being excess of Expenditure over Income for the year		401 0 7
[*1,247 8 10*]		
[*8,721 0 0*]		£9,020 11 1

No. 2. Development Fund

...ppeal for a Development Fund to be used under the direction of the Council, was made at the Annual Meeting at Dundee in 1947. The fund is still open.

	£	s.	d.
Investments at cost :			
£2,745 19*s.* 0*d.* London County 2½ per cent. Consolidated Stock, 1960/70	2,750	0	0
£2,679 1*s.* 6*d.* Bristol Corporation 3 per cent. Redeemable Stock, 1958/63	2,750	0	0
£454 11*s.* 6*d.* 3% London County Consolidated Stock, 1956/61	452	6	0
[*Value of stocks at 31/3/49, £5,505 7s. 11d.*] (Value at 31/3/50, £5,576 18*s.* 9*d.*)			
[*5,500 0 0*]	£5,952	6	0
Cash at bank	£87	19	11

EXPENDITURE	£	s.	d.	INCOME	£	s.	d.
...dministration charge [*5 13 5*]	15	11	9	By Contributions	–	–	–
Balance, being excess of Income over Expenditure for the year [*16 4*]	140	5	11	„ Dividends and Interest	119	14	4
				„ Income Tax recovered	36	3	4
[*5 9 9*]	£155	17	8	[*163 9 9*]	£155	17	8

No. 3. Caird Fund

...nconditional gift of Sir James Caird, in 1912, administered by the Council in accordance with recommendations adopted by the General Committee in 1913.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

	£	s.	d.
Investments at cost :			
£2,627 0*s.* 10*d.* 3 per cent. Savings Bonds 'A,' 1960/70	2,627	0	10
£2,716 16*s.* 6*d.* 3½ per cent. War Loan Inscribed Stock	2,516	15	5
£4,282 18*s.* 9*d.* 3 per cent. British Transport Stock, 1978/88	4,785	1	6
[*Value of stocks at 31/3/49, £9,850 10s. 11d.*] (Value at 31/3/50, £8,806 19*s.* 9*d.*)			
[*9,928 17 9*]	£9,928	17	9
Cash at bank	£505	1	2

EXPENDITURE	£	s.	d.	£	s.	d.	INCOME	£	s.	d.
...751 13 6 Grants (see Schedule)				286	2	6	By Dividends and Interest	244	11	4
...10 10 0 Administration charge				34	7	6	„ Income Tax recovered	99	4	2
...718 18 [*14 0*]				320	10	0	[*336 11 4*]	343	15	6
...217 7 Balance, being excess of Income over Expenditure for the year [– –]				23	5	6	*By Balance, being excess of Expenditure over Income for the year* [*29 2 8*]	–	–	–
...21 5 [*14 0*]				£343	15	6	[*365 14 0*]	£343	15	6
...727 5										
...159 4										
...13 6										
...619 10										
...401 0										
...020 11										

...ts authorised, not yet drawn :—

...ological Record	50	0	0
...ples Zoological Station	50	0	0
...rvival of Geography	5	0	0
...rban Geography	3	0	0
...ter-Tropical Africa	5	0	0
...ent's Cavern	10	0	0
...istory of Sheep Farming	25	0	0
International Union for the Protection of Nature	25	0	0
[*0 0*]	£173	0	0

No. 4. Toronto University Presentation Fund

...und voluntarily subscribed by members present at the Toronto Meeting in 1924. From the income a presentation of two bronze medals each year is made, together with presents of books, to selected students in pure and applied science respectively.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

	£	s.	d.
Investment at cost :			
£175 0*s.* 0*d.* 3½ per cent. War Stock	178	11	4
[*Value of stock at 31/3/49, £182 0s. 0d.*] (Value at 31/3/50, £161 0*s.* 0*d.*)			
[*£178 11s. 4d.*]	£178	11	4
Cash at bank	£5	4	9

EXPENDITURE	£	s.	d.	INCOME	£	s.	d.
Cost of medals for 1949	2	7	6	By Interest	6	2	6
Presents of books, through Toronto University	3	4	3	By Balance, being excess of Expenditure over Income for the year		1	6
Administration charge		12	3				
[*4 0*]	£6	4	0	[*6 4 0*]	£6	4	0

No. 5. Bernard Hobson Fund

The bequest of Mr. Bernard Hobson, 1933; the income to be applied to the promotion of geological research; administered by Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£50 0s. 0d. 4 per cent. Victory Bonds	55 10 5
	£601 9s. 0d. 2½ per cent. Treasury Stock, 1975 or after	601 9 0
	£416 0s. 11d. 3½ per cent. War Stock (Inscribed)	436 3 1
	£178 16s. 4d. Consolidated 2½ per cent. Stock (Registered)	150 0 0
	[*Value of stocks at 31/3/49, £1,114 13s. 0d.*] (Value at 31/3/50, £968 12s. 10d.)	
[*1,243 2 6*]		£1,243 2 6
	Cash at bank	£215 15 5

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Administration charge [*3 12 1*]	3 12 1	*By Repayment by Geological Photographs Committee of Grant (1946)* [*100 0 0*]	– – –
„ Balance, being Excess of Income over Expenditure for the year [*132 9 1*]	32 9 1	„ Interest [*36 1 2*]	36 1 2
[*136 1 2*]	£36 1 2	[*136 1 2*]	£36 1 2

Grant authorised, not yet drawn :—
Critical Geological Sections £20 0 0

[*20 0 0*] £20 0 0

No. 6. Leicester and Leicestershire Fund, 1933

The unexpended balance of the local fund for the Leicester Meeting in 1933, presented to the Association, the interest to be used assisting by scholarships or otherwise students working for the advancement of science; administered by the Council.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investments at cost :	
	£487 2s. 11d. 3½ per cent. Conversion Stock	500 0 0
	£490 5s. 11d. 3½ per cent. War Stock	500 0 0
	[*Value of stocks at 31/3/49, £1,021 8s. 2d.*] (Value at 31/3/50, £899 4s. 11d.)	
[*1,000 0 0*]		£1,000 0 0
	Cash at bank	£166 16 5

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Administration charge	3 8 5	By Interest	34 4 2
„ Balance, being Excess of Income over Expenditure for the year	30 15 9		
[*34 4 2*]	£34 4 2	[*34 4 2*]	£34 4 2

No. 7. Radford Mather Lecture Fund

A gift of £250 received from Mr. G. Radford Mather in 1936 to establish a Fund, the income therefrom to be devoted to meeting expense of triennial Lectures on Recent Advances in Science and their relation to the Welfare of the Community.

(Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.)

		£ s. d.
	Investment at cost :	
	£248 17s. 8d. 3 per cent. London County Consolidated Stock, 1956/61	250 0 0
	[*Value of stock at 31/3/49, £260 1s. 8d.*] (Value at 31/3/50, £247 12s. 9d.)	
[*250 0 0*]		£250 0 0
	Cash at bank	£43 10 6

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Lecture fee	– – –	By Interest	7 9 4
„ Administration charge	14 11		
„ Balance, being Excess of Income over Expenditure for the year	6 14 5		
[*7 9 4*]	£7 9 4	[*7 9 4*]	£7 9 4

No. 8. Arthur Haydock Bequest

A bequest received in 1945 "for the purpose of original investigation of problems relating to either or both of Geology or Botany as may be determined by the governing body of the British Association."

	£ s. d.		£ s. d.
Investments at cost :			
£2,090 4s. 0d. 3½ per cent. Conversion Stock (Registered)	2,215 12 0		
£362 6s. 3d. Consolidated 2½ per cent. Stock (Inscribed)	250 0 0		
[*Value of stocks at 31/3/49, £2,194 14s. 2d.*]	(Value at 31/3/50, £2,172 19s. 7d.		
[2,215 12 0]			£2,465 12 0
Cash at bank			£48 15 3

EXPENDITURE

	£ s. d.
To Grant (see Schedule)	5 0 0
[– – –]	
„ Administration charge	7 6 3
[7 6 3]	
„ Balance, being Excess of Income over Expenditure for the year	60 16 9
[65 16 9]	
[73 3 0]	£73 3 0

INCOME

	£ s. d.
By Interest	73 3 0
[73 3 0]	£73 3 0

Grant authorised, not yet drawn :—
Biology, etc., in the school curriculum £5 0 0

[5 0 0] £5 0 0

No. 9. Down House

In response to an appeal made in 1927 by Sir Arthur Keith, F.R.S., then President of the British Association, Mr. (later Sir) Buckston Browne, F.R.C.S., acquired the property of Down House, formerly the home of Darwin, and transferred it with an endowment of £20,000 to the Association expressing the wish that it be held in custody for the nation as a memorial to Darwin.

(*Figures in italic type and square brackets, to the left of columns, are those of the preceding year's account, inserted for comparison.*)

	£ s. d.		£ s. d.
Investments at cost :			
£3,000 Fishguard and Rosslare Railway and Harbours 3½ per cent. Guaranteed Preference Stock	2,139 17 3		
£4,311 17s. 7d. Consolidated 2½ per cent. Stock (Inscribed)	3,315 10 5		
£5,971 16s. 11d. Consolidated 2½ per cent. Stock (Registered)	5,000 0 0		
£2,444 15s. 10d. 3 per cent. Redemption Stock, 1986/96 (Registered)	2,500 0 0		
£7,380 9s. 9d. 3 per cent. British Transport Stock, 1978/88	5,449 17 2		
[*Value of stocks at 31/3/49, £21,858 10s. 5d.*]	(Value at 31/3/50, £18,383 11s. 11d.)		
[19,086 9 5]			£18,405 4 10

EXPENDITURE

	£ s. d.
To Wages of Staff	972 18 8
„ Rates, Insurance, etc. (see opposite)	72 15 4
„ Electricity	41 16 6
„ Fuel, etc.	161 0 4
„ Drainage	17 7 5
„ Water	22 9 10
„ Repairs and Renewals	53 15 4
„ Land and Garden : materials and maintenance (see opposite)	56 17 8
„ Household requisites, etc.	31 10 5
„ Printing, postage, telephone, stationery	26 12 4
„ Seismology (insurance of instrument)	1 0 0
„ Cost of claim for loss of Development Values under Town and Country Planning Act, 1947	12 12 6
„ Administration charge	93 11 8
[1,659 9 10]	£1,564 8 0

INCOME

	£ s. d.	£ s. d.
By Rents receivable		86 0 0
„ Income Tax recovered to 31st March, 1949		146 17 8
„ Dividends and Interest		522 12 8
„ Sale of catalogues, postcards and photographs		25 4 0
„ Donations received		43 5 1
„ Seismological Investigations Committee grant from Gray-Milne Trust		1 0 0
„ Sale of garden produce		6 7 6
„ Refund of rates on curator's rooms		104 10 0
[938 11 2]		935 16 11
„ Balance, being Excess of Expenditure over Income for the year, transferred to Endowment Fund		628 11 1
[720 18 8]		
[1,659 9 10]		£1,564 8 0

Schedule

Grants paid to Research Committees, etc., during the financial year to March 31, 1950.

NOTE.—The year indicated in brackets after the title of each committee is that of its original appointment, and the sum, if any, is that previously expended out of grants by the Association.

	£ s. d.	£ s. d.
1. PAID OUT OF THE CAIRD FUND (1912)		
Plymouth Laboratory (1886: £1,948 10*s.* 8*d.*)	50 0 0	
Zoological Record (1923: £1,235)	50 0 0	
Derbyshire Caves (1921: £433 15*s.* 8*d.*)	25 0 0	
"Notes and Queries on Anthropology:" Committee on re-editing (1931: £56 10*s.*)	– – –	
Final payment to Royal Anthropological Institute 73 0 0		
Less charged to general account . . 48 0 0		
	25 0 0	
Naples Zoological Station (1876: £1,200)	50 0 0	
Freshwater Biological Station, (1930: £1,337 15*s.* 11*d.*)	50 0 0	
Revival of Geography (1947)	1 2 6	
Kent's Cavern (1925: £75)	10 0 0	
Bury St. Edmunds Skull Site (1949)	15 0 0	
Map of Roman Libya	10 0 0	
		286 2 6
2. PAID OUT OF HAYDOCK BEQUEST (1945)		
Cytology and Genetics (1936: £2 18*s.* 9*d.*)		5 0 0

LECTURES FOR JUNIOR SCIENCE SOCIETIES AND CLUBS

THE Council of the British Association recently approved a report on Science Clubs for Young People prepared for, and at the request of, Unesco. This report expressed the desire of the Association to do whatever it could to help and encourage existing science clubs, to assist new clubs which may be formed in response to a real demand, and to promote co-operation between kindred groups.

One way in which it has been contemplated that the Association could help School and other Junior Scientific Societies is by suggesting the names of suitable speakers. The Association of School Natural History Societies exists to help School Societies concerned with the biological sciences, many of which have sought its advice regarding speakers. The British Association is prepared to supplement this existing service by suggesting speakers on subjects which are covered by its Sections. These are (A) Physics and Mathematics, (B) Chemistry, (C) Geology, (D) Zoology, (E) Geography, (F) Economics, (G) Engineering, (H) Anthropology and Archaeology, (I) Physiology, (J) Psychology, (K) Botany, (K) Education and (M) Agriculture.

Requests for such assistance should be addressed to The Secretary, British Association, Burlington House, London, W. 1, as far ahead as possible of the fixture it is desired to arrange. Letters should indicate the subject on which a lecture is desired, the proposed time and place of its delivery, and whether it will be possible to meet the lecturer's out-of-pocket expenses.

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